MAIZE BREEDING AND SEED PRODUCTION MANUAL

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DPR Korea
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Photo by Mr. Jon Kyong Dok, FAO DPRK
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<td>Seed Quality Control</td>
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Foreword

In the DPR Korea, maize is a major substitute for rice. It is not only a substitute crop, but also the main ingredient for livestock feeds, food production, and other industrial uses. The level of production of maize has to be substantially raised to meet the demand for food, feed and industrial use.

DPRK is noted for its harsh cold continental climate, which places severe limitations on crop production. Unfortunately, cropping activities do not go on all around the year. The continental climate would normally and reliably allow a single crop season. In the north of the country single cropping is almost always the case, but in the south the climate can allow double cropping of maize in rotation with wheat, barley or with other suitable crops though there is always a risk. The risk could be significantly reduced by introducing short duration, photo-insensitive and cold tolerant varieties of maize for cultivation as second crop.

The information on various aspects of maize breeding and seed production in the DRPK is fragmentary and scattered at diverse sources. A great difficulty is being experienced by all those concerned with maize breeding and seed production in the DPRK in getting wholesome information at one place. Therefore, the present manual is a commendable effort in direction of presenting the complete information at one place. The language of the manual is simple and easy to grasp by the students, researchers and policy makers.

The manual incorporates exhaustive information on ‘maize breeding and seed production’. I congratulate the author. I am confident that this volume would help to generate widespread awareness of the potential for increasing maize seed production speedily ultimately leading to make the DPRK self-sufficient in cereal production and saving of considerable amount of foreign exchange on import of cereal.

Last, but not the least, I would like to convey our thanks to the resource partner – UNDP for their financial contribution.

Percy W. Misika

FAO Representative in China, DPR Korea and Mongolia
Preface

As per the latest estimates/statistics available, total land area of DPRK is 122,543 square kilometres of which an estimated 17% i.e. approximately 2 million hectares is arable land under cooperative farms. Rice, maize and potato constitute the major food crops of DPRK. Of these rice and maize, DPRK’s major staple food crops, contribute respectively 45 and 34 percent to country’s food grain production. To achieve self-sufficiency in food production, a major share has to come from rice and maize crops. The level of production of maize has to be substantially raised to meet the demand for food, feed and industrial use.

I have been heartened for invaluable help received from all concerned in preparing this manual. My sincere appreciation to Mr. Percy W. Misika, FAO Representative in China, DPR Korea and Mongolia; Mr. Subash Dasgupta, Sr. Officer, FAO RAPG; Mr. Bui Ba Bong, Sr. Officer, FAO RAPG; Mr. N. S. Tunwar, Retired STA – Seed; Dr. Hari Har Ram, ex- Professor – Vegetable Breeding and Head Vegetable Science, G. B. Pant University of Agriculture and Technology, Pant Nagar, India for technical review of the manual; Mr. Belay Derza Gaga, Deputty FAOR; Mr. Ri Ung Chol, Assistant FAOR; Mr. Jon Kyong Dok, Operation Assistant; Ms. An Un Kyong, Fin. Assistant; Mr. Jon Jong Nam, National Project Coordinator; and Mr. Ri Gil Ung, Professor, Pyongyang Agricultural Campus for their technical as well as administrative support. I also wish to express my appreciation to all I have met or corresponded with, who have given valuable information. My parents, wife and children have cheerfully allowed this text to become a member of the family. I am grateful to them for their buoyancy.

The purpose of writing this manual is mainly for the benefit of extension workers, personnel involved in maize breeding and seed production, agricultural scientists and students of agricultural universities. The significant developments in maize breeding and seed production have been reviewed on all important aspects. However we must realise the limitations of covering all aspects of maize breeding and seed production in a small manual like this. Nevertheless, I believe that the latest available information on maize breeding and seed production has been covered with inclusion of several landmark key references on maize genetics and breeding for going through the original research papers by interested readers to understand the subject matter in greater detail. For the materials covered in various chapters, the underlying practices are described in view of practical utility and feasibility. No such authentic
compilation is available in DPR Korea and therefore, I am of the firm view that this manual will be quite handy for the students, researchers and policy makers particularly in DPR Korea and in general to the persons engaged in maize breeding and seed production work elsewhere as well. I am sure this compiled information will lead to stimulating discussion and interaction among the interested groups for shaping up of better maize research and seed production activities in times ahead.

Bir C. Mandal
Chief Technical Advisor
DRK/10/004 and 005 Projects
FAO Office in DPR Korea
**Acronyms**

<table>
<thead>
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<th>Description</th>
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<tr>
<td>AAS</td>
<td>Academy of Agriculture Sciences</td>
</tr>
<tr>
<td>BS</td>
<td>Breeder Seed</td>
</tr>
<tr>
<td>CFSAM</td>
<td>FAO/WFP Crop and Food Security Assessment Mission</td>
</tr>
<tr>
<td>CIAT</td>
<td>Centro Internacional de Agricultura Tropical</td>
</tr>
<tr>
<td>CGIAR</td>
<td>Consultative Group on International Agricultural Research</td>
</tr>
<tr>
<td>CTA</td>
<td>Chief Technical Adviser</td>
</tr>
<tr>
<td>CS</td>
<td>Certified Seed</td>
</tr>
<tr>
<td>DPRK</td>
<td>Democratic People’s Republic of Korea</td>
</tr>
<tr>
<td>FAO</td>
<td>Food and Agriculture Organization of the United Nations</td>
</tr>
<tr>
<td>FS</td>
<td>Foundation Seed</td>
</tr>
<tr>
<td>ISTA</td>
<td>International Seed Testing Association</td>
</tr>
<tr>
<td>MoA</td>
<td>Ministry of Agriculture</td>
</tr>
<tr>
<td>PAC</td>
<td>Pyongyang Agricultural Campus</td>
</tr>
<tr>
<td>UNDP</td>
<td>United Nations Development Programme</td>
</tr>
<tr>
<td>WFP</td>
<td>World Food Programme</td>
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</table>
Introduction and Importance of Maize in the DPRK

Corn (Zea mays L., 2n = 2x = 20) has become a leading agricultural crop and is used for food, feed, fuel and fibre in many parts of the world, not only in temperate regions but also in tropical and sub-tropical areas. Wheat, rice and corn together make-up three-fourths of the world grain production. Maize is the world’s leading crop with more than 600 million tons of production from acreage of about 138 million hectares (Ram, 2011). From average yields viewpoint, maize occupies first rank among cereals (more than 3000 kg/ha). There are six corn belts in the world. These are (i) the US corn belt, (ii) Danube basin (South West Germany), (iii) Po valley (North Italy), (iv) plains of North China, (v) North East Argentina and (vi) South East Brazil. On the world scene, the USA, China, Brazil, Mexico, France, and Argentina together account for about 75% of world corn production.

Corn is considered queen of cereals. It has C4 photosynthetic pathway which is more efficient than C3 pathway under high temperature and dry-land conditions. C4 plants are most productive in terms of food nutrients produced per unit land area, per unit of water transpired, and per unit of time under conditions suitable for C4 plants. Maize has wider adaptability and is grown from 58° N to 40° S in latitude, from sea level to 3808 m above sea level, and under 25.4 to 1016 cm rainfall. It is successfully grown on a wider scale over most of the United States, throughout Mexico and Central America to as far south as Central Argentina and Chile and South America. It is very successfully grown in Africa, Central Europe and Asia with great adaptation.

Corn shows greater degree of phenotypic diversity than other cereal crops. Morphologically/architecturally/physiologically, corn is equipped with many desirable features like sparse leaf arrangement allowing maximum light interception and minimum of mutual shading. Seed multiplication ratio (SMR) is very high whereby one seed is capable of producing a plant which in turn bears 400-1000 kernels and only 60,000 seeds are required to plant one hectare of land. Further, corn is ideally suited for hybrid seed production in view of the above desirable features and practical feasibility of hybrid seed production on commercial scale based on easy mechanical/manual detasselling/use of cytoplasmic genetic male sterility (Stoskopf, 1985).
The relevant text of the “FAO/WFP Crop and Food Security Assessment Mission to the Democratic People’s Republic of Korea (CFSAM), 28 November 2013 is quoted.

**Quote:**

DPRK’s total area amounts to 122,543 km\(^2\) (about 12.3 million hectares), of which an estimated 17 percent, or slightly more than 2 million hectares, is cultivated by cooperative farms. Of this, approximately 1.4 million hectares are considered suitable for cereal cultivation, 0.3 million hectares are under vegetable crops, some 160,000 hectares are under fruit orchards, and the balance is industrial crops such as mulberry, cotton, tobacco and ginseng. In addition, about 0.4 million hectares are farmed by Government institutions on state farms. Many of these state farms are dedicated to such activities as livestock breeding and seed production. The CFSAM considers only the production from cooperative farms.

Rice, maize and potato constitute the major food crops of DPRK. Of these rice and maize, DPRK’s major staple food crops, contribute respectively 45 and 34 percent to country’s food grain production. Maize is more universally distributed than paddy and is normally grown under rain-fed conditions. **DPRK is the only country in the world to transplant maize on a large scale in order to accommodate double-cropping and to give the crop a good early start in what is a relatively short growing season.** In 2013, maize area of 527,317 hectares was 0.7 % smaller than the approximately 531,000 hectares in 2012. Self-sufficiency in food production is a national priority.

A total of 5.98 million tonnes of food output (including paddy, cereals, soybeans, and cereal equivalent of potatoes) from cooperative farms, plots on sloping land, and household gardens for 2013/14 is expected. This estimate includes the 2013 main season harvest that was concluded and the forecast for 2014 early season crops. When paddy is converted to milled rice and soybeans to cereal equivalent, total food production is estimated at about 5.03 million tonnes. Based on the CFSAM’s estimate of total utilization needs of 5.37 million tonnes of cereal equivalent (rice in milled terms), the Mission estimates a cereal import requirement of 340,000 tonnes for the 2013/14 marketing year (November/October). Assuming the official import target of 300,000 tonnes of cereals is met, the Mission estimates an uncovered food deficit of 40,000
tonnes for the current marketing year. This food gap is the narrowest in many years, and is mainly due to the higher 2013 production. Despite the improved harvest, the food security situation remains similar to previous years with most households having borderline and poor food consumption.

Unquote

Thus it is obvious that to achieve the targeted requirement of food crops, a major share has to come from rice and maize crops. However, practically there is very little scope of area expansion under major food crops. Further, there are limitations of irrigation potential, slow pace of technology development for ecologically handicapped ecosystems (sloping land), fast eroding soil health and continuously changing disease-insect pest complex. In fact, natural resources like land and water have been stretched to the limit. Another development of great concern is the fact that in irrigated ecosystem, which contributes major share of the rice production advances made so far, yield levels of high yielding varieties (non-hybrid) are getting plateaued (4.3 t/ha).

The limitation of availability of additional cultivable area and technological compulsions are equally applicable on maize crop. The level of production of maize has to be substantially raised to meet the demand for food, feed and industrial use. DPRK is noted for its harsh cold continental climate, which places severe limitations on crop production. Unfortunately, cropping activities do not go on all around the year. The continental climate would normally and reliably allow a single crop season. In the north of the country single cropping is almost always the case, but in the south the climate can allow double cropping of maize in rotation with wheat, barley or with other suitable crops though this is always a risky proposition. The risk could be significantly reduced by introducing short duration, photo-insensitive and cold tolerant varieties of maize for cultivation as second crop. Usually, wheat and barley are harvested at the end of June or early July. A short duration cold tolerant maize hybrid which could be transplanted in July and harvested in late October could easily fit in double cropping system. In this way crop intensification will be only in the time dimension and no extra land will be required. However, in addition to boosting the production through increased cropping intensity, there should be more focus on increasing total production of maize and other cereals to mitigate the perpetual problem of food shortage in DPRK through boosting productivity i.e. yield per unit area.
The entire area under maize in DPRK is covered by hybrid varieties. Therefore, breeding research and seed production of superior hybrids of maize should be accorded top priority and accordingly concerted efforts need to be intensified in this direction. Continuous monitoring of the production statistics of major food crops is necessary for identifying the major constraints in productivity, reallocating production resources and, if necessary, redesigning the research priorities and programmes. Agriculture production related statistics for DPRK are shown in Table 1. A perusal of Table 1 shows that maize is the second most important crop of DPRK after paddy and deserves due attention in breeding research and seed production.

Table 1. DPRK – Main-season crop area, yield and production of grains and potatoes in 2013; farm production only

<table>
<thead>
<tr>
<th>Province</th>
<th>Paddy</th>
<th>Maize</th>
<th>Potato</th>
<th>Soybeans</th>
<th>Other cereals</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area '000 ha</td>
<td>Yield t/ha</td>
<td>Prod '000 t</td>
<td>Area '000 ha</td>
<td>Yield t/ha</td>
<td>Prod '000 t</td>
</tr>
<tr>
<td>Pyongan</td>
<td>12</td>
<td>6.3</td>
<td>76</td>
<td>4</td>
<td>4.6</td>
<td>16</td>
</tr>
<tr>
<td>S Pyongan</td>
<td>82</td>
<td>6.2</td>
<td>514</td>
<td>65</td>
<td>3.5</td>
<td>225</td>
</tr>
<tr>
<td>N Pyongan</td>
<td>10</td>
<td>5.8</td>
<td>586</td>
<td>80</td>
<td>4.0</td>
<td>322</td>
</tr>
<tr>
<td>Chagang</td>
<td>7</td>
<td>3.7</td>
<td>25</td>
<td>34</td>
<td>3.1</td>
<td>104</td>
</tr>
<tr>
<td>S Hwanghae</td>
<td>14</td>
<td>5.2</td>
<td>757</td>
<td>96</td>
<td>4.3</td>
<td>419</td>
</tr>
<tr>
<td>N Hwanghae</td>
<td>57</td>
<td>4.6</td>
<td>262</td>
<td>83</td>
<td>4.1</td>
<td>342</td>
</tr>
<tr>
<td>Kangwon</td>
<td>29</td>
<td>4.1</td>
<td>117</td>
<td>38</td>
<td>3.2</td>
<td>119</td>
</tr>
<tr>
<td>S Hamgyong</td>
<td>59</td>
<td>4.6</td>
<td>271</td>
<td>49</td>
<td>3.8</td>
<td>185</td>
</tr>
<tr>
<td>N Hamgyong</td>
<td>27</td>
<td>3.9</td>
<td>104</td>
<td>60</td>
<td>3.0</td>
<td>180</td>
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<tr>
<td>Ryanggang</td>
<td>1</td>
<td>2.7</td>
<td>4</td>
<td>9</td>
<td>4.0</td>
<td>35</td>
</tr>
<tr>
<td>Nampo City</td>
<td>27</td>
<td>6.9</td>
<td>184</td>
<td>10</td>
<td>5.5</td>
<td>54</td>
</tr>
<tr>
<td>DPRK total</td>
<td>54</td>
<td>5.3</td>
<td>290</td>
<td>52</td>
<td>3.8</td>
<td>200</td>
</tr>
</tbody>
</table>

Source: MoA
Remarks: Potatoes in cereal equivalent at 25 percent conversion rate.

DPRK is noted for its harsh cold continental climate, which places severe limitations on crop production. Consequently, cropping activities cannot go on all around the year. The continental climate reliably allows a single crop season. In the north of the country single cropping is almost always the case, but in the south, there is scope of double cropping though this is always confronted with a fair degree of risk. The typical planting and harvesting time of important cereal crops in DPRK is shown in Table 2.
Table 2. Planting and harvesting time of cereal crops in DPR Korea

<table>
<thead>
<tr>
<th>S. No</th>
<th>Crop</th>
<th>Planting/sowing time</th>
<th>Harvesting time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Rice</td>
<td>June</td>
<td>October/November</td>
</tr>
<tr>
<td>2.</td>
<td>Maize</td>
<td>April</td>
<td>September</td>
</tr>
<tr>
<td>3.</td>
<td>Wheat</td>
<td>November</td>
<td>June</td>
</tr>
<tr>
<td>4.</td>
<td>Barley</td>
<td>November</td>
<td>June/July</td>
</tr>
</tbody>
</table>

Very rightly, maize occupies a significant place in agricultural system of DPRK and adequate attention on breeding and seed production research intensification will easily add to increased corn production leading to over all increased grain production which is very much needed.

Origin and Evolution of Maize

The maize is considered to be indigenous to the Americas particularly Southern Mexico. It has been domesticated about 8000 years ago and does not survive in its wild form. There was evolution of high yielding dent kernel cultivars adapted to the Central Corn Belt and the Eastern and the Southern regions of the USA by American farmers in early days. Simultaneously, early maturing flint kernel type cultivars evolved in the Northern USA. Poehlman and Sleper (1995) have given a detailed account of maize breeding including its evolution. According to this compilation, it is generally now accepted that the teosinte (Zea Mexicana), the nearest known relative of corn, has been progenitor of corn. Opinion is still divided as to whether corn originated by a single domestication from the basal branching teosinte subsp. Zea mays L. spp. Parviglumis or from the lateral branching subsp. Zea mays L. spp. Mexicana, or by a dual domestication from two subspecies. Transformation of maize from teosinte involved evolutionary forces such as mutation, hybridization, genetic drift and selection aided by selective and useful interventions by human beings, who selected useful variants out of large populations of teosinte and concentrated them into isolated evolutionary pools. This resulted in differentiation of maize into over 300 races. The races gradually got adapted to different agro-climatic regions in the Americas away from the centre of origin. Some scientists suggested multi-centre origin of maize on the basis of wide diversity with respect to cytological,
morphological and physiological characteristics and their early widespread distribution. Galinat (1988) suggested a hypothesis of two-stage origin of maize. Initially, there was inadvertent selection within teosinte and later, there was genetic construction of maize by deliberate selection for its key traits such as (i) paired female spikelets in maize in comparison to solitary spikelets in teosinte, (ii) many-ranked ear and tassel which is unique in maize in the entire tribe Maydeae in comparison to a two-ranked central spike in teosinte and (iii) non-shattering rachis (cob) in maize in comparison to shattering cob in teosinte. There was an enhancement and stabilization of such key traits in maize, together with a suppression and destabilization of the teosinte ones.

On the basis of morphological data, there have been suggestions that there has been extensive gene flow between maize and teosinte and that the genetic constitution of teosinte has been greatly altered by maize germplasm. Molecular studies have confirmed that there is a two-way gene flow, but at a low level. Consequently, maize and teosinte maintain distinct genetic constitutions despite sporadic introgression (Doebley, 1990). Details are available in Dhillon and Prasanna (2001).

**Taxonomy**

The genus *Zea* typically characterized by terminal male inflorescences with paired staminate spikelets and lateral female inflorescences with single or paired pistillate spikelets contains four species as given below:

i) *Zea mays* (2n = 2x = 20) - corn

ii) *Zea Mexicana* (2n = 2x = 20) – annual teosinte

iii) *Zea perennis* (2n = 4x = 40) – perennial tetraploid teosinte

iv) *Zea diploperennis* (2n = 2x = 20) – perennial diploid teosinte

Maize and teosinte are usually classified as domestic and wild species, respectively. Teosinte is native to Mexico and Guatemala and may be found growing wild quite often. It crosses readily
with cultivated corn and the hybrids produced are fertile. Teosinte like corn is monoecious but produces dispersible seeds (6-12 only) in hard, triangular shell like structures.

The genus *Tripsacum* is a close relative of genus *Zea*. It is characterized by bisexual terminal and lateral inflorescences. The lower portion of each inflorescence branch is female and the upper section is male. There are 11 species in the genus *Tripsacum* as described by de Wet and Harlan (1978). The 11 species are listed below.

i. *T. andersonii*, 2n = 64
ii. *T. austral*, 2n = 36
iii. *T. bravum*, 2n = 36
iv. *T. dactyloides*, 2n = 36, 54, 72
v. *T. floridanum*, 2n = 36
vi. *T. lanceolatum*, 2n = 72
vii. *T. latifolium*, 2n = 72
viii. *T. laxum*, 2n = 36
ix. *T. maizar*, 2n = 36
x. *T. pilosum*, 2n = 72
xi. *T. zopilotense*, 2n = 36

All the 11 listed species are perennial and may be found growing in Mexico, Central America and the South-Eastern USA. The wild and domestic diploid *Zea* species, namely, *Zea mays*, *Zea diploperennis*, *Zea Mexicana* and *Zea luxurians* (n = 10) cross freely and their hybrids are fully fertile. However, there is a perennial tetraploid (n = 20) species (*Zea perennis*) which is now extinct in the wild but is still maintained. Tetraploidy in maize appears to be of recent origin and its perennialism is probably of ancient derivation from an ancient *Zea* ancestor that was both diploid and perennial. The genus *Tripsacum* (Gamma grass) and/or its ancestors have a different basic chromosome number of x = 9. This genus includes at least 5 diploid (n = 18) and 4 tetraploid (n = 36) species which are all perennial. They are of diverse morphology and are adapted to a wide range of habitats throughout much of the new world. The crosses between
maize and *Tripsacum* are made with difficulty. The resultant F₁ hybrids are only partially female fertile and fully male sterile (Galinat, 1988; Dhillon and Prasanna, 2001).

**Botany**

Maize belongs to tribe Maydeae and the family Graminae now known as Poaceae (the grass family). Maize plant has 2-3 m tall single stem with single leaf at each node. The leaves are arranged on the principal stalk in two opposite ranks. Each leaf has a sheath surrounding the stem, and an expanded leaf blade connected to the sheath by a blade joint. The number of leaves on a plant may range from 8 to 48.

Maize is monoecious i.e. the male and female flowers are borne separately on the same plant. The male inflorescence also known as tassel is located at the top of the stem. Tassel is a branched panicle in which paired spikelets (one sessile and one pedicelled) are produced on both, the central axis and the branches. Each spikelet has two lowermost empty bracts called glumes and two staminate florets. Each floret has three stamens enclosed by lemma and palea.

The female inflorescence also known as cob or ear is placed at somewhat mid-height on a node on the main stem or stalk. The female inflorescence is considered as a modified lateral branch arising from an axillary bud on the main stem. The internodes of this lateral branch are telescoped to form a stout axis. There are modified leaves in the form of overlapping sheaths originating from the lower node of the axis to cover the female inflorescence or the cob. These overlapping leaf-sheaths are called as husks. On ear shoot/cob, pistillate spikelets are borne in pairs in longitudinal rows. There are two flowers/florets in each spikelet. One flower is fertile and the other sterile. Because of this, there are even numbers of rows of kernels on each ear/cob. One stalk may bear 1-3 cobs. The hair-like structures emerging out of top of the husks are known as silk. Silk functions both as stigma and style. The corn pollen tubes are the longest known in plant kingdom. The silks are receptive throughout the entire length to receive fresh pollen grains.

**Floral Biology and Crossing**

Maize is monoecious with determinate growth habit and highly cross-pollinated where about 95% of the pistillate flowers on a cob receive pollen from nearby other plants. About 5% of the
kernels on a cob are produced as a result of self-pollination. Maize is generally protandrous, that is, male spikelets mature earlier than the female spikelets. The pollen shedding normally begins 1-3 days before the emergence of silk and continues 3-4 days after the silks are receptive and ready for pollination. According to Poehlman (1987), a single tassel may produce as many as 25,000,000 pollen grains or an average of over 25,000 pollen grains for each kernel on an ear with 800-1000 kernels. Pollen grains are very small, barely visible to naked eye, light in weight, and easily carried by wind. Wind borne nature of pollen and protandry facilitate cross-pollination, but 5% self-pollination may happen. Pollen grain viability is for about 12-18 hrs and thereafter they may be killed in few hrs by heat or desiccation. In hot, dry and windy conditions, the pollen shedding may be over early. Under these conditions, the tassel may be injured or the silk may lose the moisture and as a result, barren cobs are produced.

For crossing purpose, the top of an ear before emergence of the silk is cut by a sharp razor and covered with butter paper bag. Simultaneously, the tassel of the desired male parent is covered with tassel bag. The anthesis (dehiscence of anthers) starts from the central shoot of the tassel. It starts from the top and proceeds downwards. The covering of tassel is done on those male parents in which one-fourth of the tassel has dehisced. Pollination is done when a uniform growth of silk is visible on the cobs covered with butter paper bag. The tassel bag containing freshly shed pollen is transferred over the cobs after removing the butter paper bags from the cobs.

Before putting tassel bags on the tassel, all details like date of pollination and breeding programme are should be clearly written on the bags by water-proof pencil. In order to avoid contamination and to get enough fresh pollen, the tassel bags are put on tassel one day earlier than pollination. This clearly means that the date of pollination will be one day later than the date of tasselling. The tassel bags are held in position with the help of U clips.

If there are two plots (plot 1 and 2) being used in crossing programme, and if plot 1 is used as male then X 1 is written on the tassel bag. Female plot numbers are generally not written. For self-pollination, pollen of the same plant is used to pollinate the cob on the same plant. The sign used on tassel bag for selfing is 🍼. For sibbing, pollen from one plant is used to pollinate the adjacent plants within the same plot i.e. to pollinate sister plants. For bulk sibbing, pollen from
one half of the rows are used to pollinate the other half plants in the same row. The sign used for sib-pollination is # and for bulk sibbing (#). A few important points worth mentioning while doing pollination are as follows:

i) Bagging of the tassel should be done one day in advance in previous evening to avoid contamination from foreign pollen.

ii) Date of pollination and name of programme must be written on the tassel bags with water-proof pencil.

iii) Date of pollination is one day later than the date of tasselling.

iv) Pollination must be completed within 3-4 hrs after removal of anthers to ensure viability of pollen.

v) Pollination must be completed within one week of silk emergence.

Maize Genetics, Corn Type Races and Genetic Resources

The genetic stocks of maize lines with known qualitative genes are maintained at University of Illinois, Urbana Champaign. A maize Genetics Cooperative Newsletter (MNL) is published by the USDA and the Department of Agronomy, University of Missouri, Columbia. This publication is a source of information on different qualitative genes for corn geneticists and breeders. Coe and colleagues (1988) have compiled a comprehensive list of genes of maize. Detailed studies in maize have shown the existence of more than 1000 loci. These loci are responsible for a variety of biosynthetic pathways, chemical constituents, agronomically important traits and developmental traits and these have been mapped on 10 chromosomes. A large number of loci have been identified and mapped for proteins, enzymes, restriction fragment length polymorphisms (RFLPs) and simple sequence repeats (SSRs) or microsatellites that are detected on the basis of segregation of polymorphic alleles under electrophoretic conditions.

Maize continues to serve as one of the model genetic plants for exploring the phenomena such as transposition and paramutation, and for exposition of genetic theories that are of
considerable importance to breeding of crop plants in general and cross-pollinated crops in particular. The discovery of mobile genetic elements or transposons in maize by Nobel laureate Barbara MaClintock in 1950 has worked as foundation for analysis of gene mutation and regulation (Peterson, 1987). Element systems such as Activator/Dissociation (Ac/Ds), Suppressor-Mutator (Spm) and Mutator (Mu) have been analysed in greater details at genetic and molecular levels. These transposable element systems have proved to be useful tools to isolate several agronomically important genes like disease resistance, endosperm quality, plant development, sex determination, male fertility etc., via transposon tagging in maize (Shepherd, 1987; Sundaresan, 1996).

A very significant genetic event in maize is xenia. Xenia is immediate effect of pollen on the developing kernel. It may be observed when two varieties differing in a single visible endosperm character are crossed. Xenia occurs when the trait difference is caused by a dominant gene present in the pollen. However, when dominance is incomplete, xenia will occur when either variety is the pollen parent. Xenia is important as endosperm characteristics distinguish some of the major corn groups. For example, starchy endosperm is dominant over sugary (sweet) and waxy endosperm. A cross of starchy x sugary exhibits xenia. Similarly, a cross of shrunken x non-shrunken endosperm, waxy x non-waxy endosperm, purple x colourless aleurone and yellow x white (colourless) endosperm, all show xenia (Acquaah, 2007).

Based on kernel types, maize has been classified into 7 kernel types, namely, dent, flint, floury, pop, sweet, waxy and pod kernel types. Of these, five types, namely, dent, flint, floury, sweet, and waxy are commercially produced. A brief description of these races based on endosperm and glume characteristics is as follows (Acquaah, 2007).

1. **Dent Corn:** Dent corn is the most widely cultivated type in US. It is characterized by a depression (dent) in the crown caused by the rapid drying and shrinkage of the soft starch at the crown. Of the multiple colours available, the yellow and white colours dominate the commercial production.

2. **Flint Corn:** Flint corn is predominantly composed of corneous or hard starch that encloses the soft starch at the centre. The kernels are smooth, hard, and usually rounded
at the top. This type of corn is widely grown in Europe, Asia, Central America and South America. It is grown less in US.

3. **Floury Corn:** Floury corn consists almost entirely of soft starch and accordingly the kernels are soft. It has the shape of dent corn but shrinks uniformly upon drying.

4. **Pop Corn:** Pop corn is an extreme form of flint corn. It has very hard corneous endosperm with only a small portion of soft starch. The kernels are small and may either be pointed or have rounded tip. The most common colours of the kernels are yellow or white. The kernels pop upon heating as a result of the unique quality of endosperm that makes it resist the steam pressure generated until it reaches explosive proportion.

5. **Sweet Corn:** This corn kernel is characterized by a translucent and wrinkled appearance upon drying. The immature kernels are sweet in taste. Standard sweet corn is a mutant of dent corn with a mutation at the sugary (sy) locus. This mutation causes the endosperm to accumulate about two times more sugar than the field corn. New mutants have been discovered. These are sugary enhanced (se) and shrunken-2 (sh2) or super sweet corn.

6. **Waxy Corn:** Wax corn has a uniformly dull appearance. Instead of amylose, the starch of waxy corn is amylopectin as a result of waxy (wx) mutation. Ordinary corn consists of about 78% amylopectin (a high molecular weight branched chain starch) and 22% amylose (a low molecular weight straight chain starch).

7. **Pod Corn:** Pod corn has primitive features, each kernel being enclosed in a pod or husk, before the entire ear is enclosed in husks like other corns.

Commercially, Corn Belt Dents, Southern Dents and Northern Dents are predominant types.

Subsequently, a broader concept of maize races came into existence. A maize race is defined as a group of related individuals with enough characters in common to permit their recognition as a group. A number of workers have contributed to the development of racial concepts in maize, particularly through analysis of races in Central and Southern America, the USA, India and other parts of the world. The US Corn belt Dent race, a hybrid of northern flints and southern dents is considered the most productive race. A wide range of
maize germplasm/races is available in the tropical countries of the maize growing regions and the important racial complexes from these regions include, Tuxpeno, Cuban, Flints, Tuson, ETO and Coastal Tropical Flints. These races have been widely used throughout the world in maize improvement programmes.

The source of various kinds of maize germplasm/genetic resources is the International Centre for Maize and Wheat Improvement (CIMMYT) established on April 12, 1966, to increase quantity and quality of maize and wheat and alleviate hunger in the developing countries of the world. Its centre of operation is at El Batan, just outside of Mexico City, but its outreach spans the globe with major programmes in Latin America, Africa, and Asia. More than 9 million ha of world’s maize crops are estimated to be seeded to CIMMYT-related varieties and there is solid evidence of increasing utilization of CIMMYT germplasm in national programme in tropical and sub-tropical countries, and even in temperate regions. CIMMYT has been focusing on recurrent selection at population level. Over 13,000 accessions of corn are stored at CIMMYT in Mexico with duplicates of these accessions held in the US (at US Seed Storage Laboratory, Fort Collins, Colorado), Columbia and Peru. Any organization intending to scale up its maize breeding activities must have a close linkage with CIMMYT for access to good germplams and manpower training.

**Breeding Objectives**

High yield is considered to be the most important trait in any maize breeding programme and this is more applicable to maize breeding project in DPRK where yields are not to the level of those in the temperate regions of the world. The next important traits in that order should be early maturity, disease resistance, reduced plant height, reduced ear height, drought tolerance, cold tolerance, grain type. Other traits to be given due consideration will be lodging resistance, insect resistance, tassel size, stability, protein quality, plant type and prolificacy.

Grain yield in maize like in other crops is a complex and quantitatively inherited traits. Maize yield is cumulative effect of action and interaction of several yield components like, number of ears/plant, kernel rows/ear, kernels/row, test weight (kernel weight) and shelling percentage. In addition to these primary yield components, there are several secondary yield
components and these include nutrient uptake, photosynthesis, translocation, sink size, transpiration and respiration. Grain yield is also affected by maturity duration, standability, and resistance to biotic and abiotic stresses. It has been generally seen that high yielding hybrids developed have longer duration and grain filling period (early flowering and delayed senescence), rapid grain filling period, increased sink size (more kernels per unit area), larger kernels, reduced bareness, higher harvest and shelling indices, shorter plant and tassel, upright leaves, shorter anthesis-silking interval, better adaptability, superior disease and insect-pest resistance and enhanced tolerance to abiotic stresses. Further, two additional features that contribute towards higher yield in maize are ability to respond to higher levels of nitrogen and suitability for cultivation under high plant population.

Good standability contributes enormously towards higher yield in maize. Well developed root system, strong stem, short plant height, low ear placement, ability to stay green at maturity and resistance to diseases and insects are major factors affecting maize standability (Dhillon and Prasanna, 2001). These characters are of universal applicability.

Stability of yield performance is important from view point of having high and stable yield across a wide range of environments prevailing in DPRK. For this to happen, resistance to diseases and insects and tolerance to drought and cold are very important considerations in the maize breeding programme of DPRK. Under certain conditions, focus can be given to specific adaptation to a given agro-climate to have the best possible yield under a niche environment. From stability view point, double cross hybrids may be superior to single cross hybrids as single cross hybrids possess only individual buffering whereas double cross hybrids possess individual as well as population buffering. However, there are indications that it is possible to develop highly stable single cross hybrids in maize.

Breeding for appropriate maturity is an important consideration in maize breeding programme. Maize is a short-day plant and accordingly time of flowering is influenced by temperature and photoperiod. Traits related to maturity are days to flower, brown husk, kernel moisture at harvest and black layer formation. Days to silk are considered to be the most reliable index of days to maturity. Genetically, days to maturity are quantitatively inherited trait and selection at inbred line development has been found to be effective to
design parents/hybrids with appropriate maturity. And it should also be kept in mind that there is a negative correlation between days to maturity and grain yield and therefore in view of prevailing agricultural system, the emphasis on early or mid or late duration cultivars should be decided. Early maturing cultivars are preferred under rain-fed conditions whereas they escape drought. Long duration cultivars are useful when the cropping system permits them and the crop management is quite good. Under DPRK conditions, it will be better to go for early/medium duration cultivars to avoid adverse effect of harsh weather which sets on early.

The important diseases to be looked into are leaf blights, downy mildews, stalk rots and rusts. The genetic control of these diseases varies from oligogenic to polygenic and pedigree method to back-cross method of breeding has been found to be effective for disease resistance breeding. In view of large number of diseases affecting maize, emphasis should be on multiple disease resistance breeding. Among several insect pests of maize, stem borer and European corn borer (*Ostrinia nubilalis*) are considered as serious insect under DPRK conditions.

Damage due to drought is manifested as top firing, tassel blast and poor seed set which may be due to non-availability of viable pollen, drying of silk or embryo sac abortion. Some morphological traits associated with drought tolerance are synchronised male and female flowering (reduced anthesis-silking interval), small tassel, small leaf area, prolificacy, adaptation to high plant population/density, well developed root system, leaf elongation during drought period, stomatal resistance to water loss, heat tolerance, and low leaf temperature. However, reduced anthesis-silking interval and number of ears/plant under drought are considered the best indicators of drought tolerance in maize and naturally more attention needs to be given to these traits while developing inbreds and hybrids in maize (Dhillon and Prasanna, 2001).

Cold tolerance is always an important breeding objective in temperate maize as is the case with DPRK. The important factors to enhance cold tolerance include improvement in the ability of seed to germinate and of seedlings to grow faster and rapid dry-down of kernels
under cold conditions. The emphasis on these traits has led to development of maize hybrids suitable for higher altitudes, particularly in the northern hemi-sphere and advancing sowing dates and thereby increasing the crop duration and yield potential. Review by Miedema (1982) is an important source of valuable information on this aspect.

There has been remarkable progress in developing new cultivars of maize with increased starch, oil and protein in kernels and in some cases in altering the quality of these constituents. For example, the genes that modify either the structure or the quality of kernel endosperm, have been effectively used to develop speciality corns world over (Hallauer, 1994). In sweet corn, several genes, such as sucrose (su), shrunken-2 (sh-2), amylose etender (ae), brittle (bt), brittle-2 (bt-2), dull (du), and waxy (wx) have been used to enhance the flavour and tenderness. A breakthrough has been realised with the discovery of opaque-2 (o2) gene by Mertz et al. (1964). Opaque-2 gene has been shown to double the content of lysine and tryptophan in the maize endosperm. Opaque maize has also proved to be nutritionally superior in feeding experiments. The use of this gene in maize breeding programmes led to development of several stocks/cultivars often known as Quality Protein Maize (QPM). The high lysine cultivars had initially some inherent problems like low grain yield, dull and soft grain, delayed maturity, susceptibility to some diseases and insects and processing problems due to soft endosperm. However, intensive efforts by CIMMYT led to development of QPM populations and heterotic pools by large scale back-crossing of improved o2 donor stocks followed by recurrent selection to accumulate modifiers to improve kernel vitreousness, hardness and other desirable traits while retaining nutritional superiority.

**Breeding Methods**

Maize is highly cross-pollinated crop. Its population comprises of freely interbreeding individuals and is heterogeneous. As a consequence, the plants in a maize population are heterozygous at most of the loci. From breeding viewpoint, maize is thus highly adapted to heterozygosity, which is an essential feature of maize cultivars. Therefore, heterozygosity has to be maintained or restored in the end commercial product. Inbreeding leads to inbreeding depression resulting in reduction in vigour, size and yield and appearance of lethals and sub-lethals. Therefore, inbred lines cannot be adopted as commercial products. The
heterozygosity has to be brought back through breeding processes in the commercial products. Ultimately the commercial cultivars may be open-pollinated populations (synthetics or composites) and hybrids. The choice of cultivar depends upon resources, stage of breeding programme, infrastructure and manpower for seed production and socio-economic factors. Hybrid cultivars have the advantage of higher yield potential and uniformity. They are preferred over open-pollinated populations subject to higher level of heterosis. However, seed production of hybrids is costlier and a bit tedious and complicated (Dhillona and Prasanna, 2001).

Basically, maize breeding methods consist of population improvement and hybrid breeding. The most important step in any breeding programme is selection which is discrimination among individuals in the number of offsprings contributed to the next generation. Selection brings about changes in gene and genotype frequencies and results in improvement of genotypic value of trait(s) under consideration. Selection is effective only on already existing variability that has its origin in spontaneous mutations and that gets dispersed through natural hybridization, gene segregation and recombination. The naturally occurring genetic variability may be reinforced by induced mutations and planned hybridization.

Common breeding procedures currently in use in maize improvement are listed in the following Table 3 (Ram, 2011).

**Table 3. Maize breeding procedures**

1. **Population improvement**
   a. **Intra-population selection**
      i) Mass selection
      ii) Modified mass selection (Gardner method)
      iii) Half-sib selection with progeny test or ear-to-row selection (no replication-Hopkins method)
      iv) Modified ear-to-row selection (replicated test-Lonnquist method)
v) Half-sib selection with test cross

vi) Full-sib selection

vii) $S_1$ family selection

b. **Inter-population selection**

i) Reciprocal recurrent selection (Comstock and colleagues)

ii) Full-sib reciprocal recurrent selection (Hallauer, Lonnquist, Williams)

1. **Synthetic varieties**

2. **Composite varieties**

3. **Hybrids**

Various breeding procedures as listed in the above Table 3 are briefly described as follows:

**Mass Selection:** This is the oldest, simplest and least expensive method of selection for cross-pollinated crops, particularly maize. This consists of selection of ears on the basis of plant and ear characteristics and bulking of seeds of harvested ears to grow the following generation in which again another cycle of selection can be initiated. Cycle of selection is completed in one season. This process can be repeated for several cycles till substantial gains are realized. This method although simplest in operation has certain limitations like inability to identify superior genotypes on the basis of phenotypic performance alone and no control over pollen parent where inferior plants also contribute their pollen. Further, rigorous selection for specific plant trait often leads to inbreeding. Additional limitation is that selection is based on single plant, therefore the role of environment may affect the plant performance and one may select the plants which may be potentially not up-to mark. Therefore, this method has been subjected to some modifications.

**Modified Mass Selection:** This has been proposed by Gardner in the year 1961. In this method, the source population in which selection has to be done is grown in isolation at a low plant density to allow better phenotypic expression of each individual plant. The whole area is divided into sub-plots or grids. Selection for superior ears on superior plants is done in each grid.
Selected ears across the grids are bulked. This method of selection is also known as stratified mass selection.

**Half-sib Selection With Test Cross or Ear to Row Selection:** In this method, phenotypically superior ears are selected from superior plants from a source or base population grown in isolation. Seeds from harvested ears (half-sib-seeds, one parent common) are kept separate unlike mass selection where the seeds from different ears are bulked. Seed from each selected ear is divided into two halves. In second year, half of seeds from each ear is used to grow progeny row in isolation for evaluation. Remnant seeds are kept separately. In third year, a new population is reconstituted from by bulking equal quantity of seeds either from harvested superior progenies or from the remnant seeds which gave rise to superior progenies.

**Modified Ear to Row Selection (MER-Lonnquist Method):** This is a modification of ear to row, a type of half-sib selection in which half-sib families are planted in different environments for evaluation. The experiment in one environment is sown as an isolated evaluation-cum-recombination block. In this block, ear-to-rows are inter-planted with a balanced male (BM) composite developed by mixing an equal number of seeds of all ears under evaluation. The ear-to-rows are detasselled and are thus pollinated by the pollen of BM composites. Selection is carried out among and within families, selection among ear-to-rows being based on performance across the target environments and that within ear-to-rows being mass selection in isolated block. MER selection is a unique method of family selection as one cycle of selection is completed in one season but it provides no control over pollen parent. It has been used by many breeders including those at CIMMYT. Operational steps of this method are as follows (Mukherjee, 1989a; 1989b).

i) 100 or more ears are selected from a base population based on grain and agronomic characters. Each ear is shelled separately (I season).

ii) Seeds of each selected ear are grown as progeny row in single replication at different locations of the environment for which the new variety is to be developed (II season).

iii) Replicate at the main station is handled as a crossing block. A balanced mixture of seed is used as pollen parent. For creating balanced mixture, equal number of seeds are taken from each progeny and mixed (II season).
iv) At the main location, five phenotypically superior plants in each progeny row are marked. Five ears from the marked plants are kept in a bag after each row is harvested and weighed (II season).

v) Top 20% of the progenies are selected on the basis of average performance over locations and five ears/cobs from each of these 20% of selected progenies (100 cobs, if number of planted progenies is 100) are grown in next season in ear-to-row manner (III season) and above cycle may be repeated.

**Half-sib Selection With Test Cross/Half-sib Progeny Selection:** Individuals having one parent common are called as half-sibs. In half-sib breeding, the selected plants are always test crossed. Two different terms are used in this method depending upon as to how the next population is reconstituted. These terms are:

a. **Half-sib progeny test:** Under this scheme, males are selfed and crossed to females to produce half-sib families. Selfed seeds from selected males are composited to reconstitute the next population.

b. **Half-sib test:** It is similar to half-sib progeny test except that compositing is done from open-pollinated seeds. The steps are as follows:

I Season: Selection of superior plants (50-100) in a source population, crossing to a tester, and selfing under half-sib progeny test and crossing only to a tester under half-sib test.

II Season: Evaluation of testcross progenies.

III Season: Compositing selfed seeds from plants with superior testcross progenies under half-sib progeny test and compositing open-pollinated seeds from plants with superior testcross progenies under half-sib test. Under half-sib progeny test if tester is broad based, the procedure is similar to recurrent selection for general combining ability and if the tester is an inbred line, then procedure is equivalent to recurrent selection for specific combining ability.

**Full-sib Selection:** Individuals having both the parents common are known as full-sibs and are derived from crossing of two selected plants from the base population. The crosses are made between selected pairs of plants in the source/base population. Crossed seeds are used for progeny test and for reconstituting the improved new base population. The basic procedure is depicted in Fig 1.
**S₁ Progeny Testing/Selfed-Progeny Selection:** The selfed progeny is produced in a base/source population by one (S₁), two (S₂) or more selfings. The progenies are evaluated and selected ones are recombined using remnant seeds. Mostly S₁ or S₂ selection is carried out but there are instances where selection has been done even in S₃. For some characters like disease and insect-pest resistance, selfed progeny (SP) selection has given higher gain than other methods. However, the gains through SP selection are adversely affected when the contribution of non-additive variation is higher.

Fig. 1. Full-sib selection
**Reciprocal Recurrent Selection/Half-sib Reciprocal Recurrent Selection:** This procedure proposed by R. E. Comstock, H. F. Robinson and P. H. Harvey in 1949 aims at simultaneous improvement of two heterozygous and heterogeneous populations (designated as A and B) where population A serves as tester for population B and vice-versa. This method is as effective as recurrent selection for general combining ability when additive gene action predominates, and is as effective as recurrent selection for specific combining ability when non-additive gene action are of major importance in deciding the genetics of a particular trait. The operational steps involved are as follows:

I Season: Selected plants of population A are self-pollinated and crossed to plants of population B. Likewise, plants are selected and self-pollinated in population B and out-crossed to plants of population A.

II Season: Test cross progenies of both the populations are evaluated in replicated trial. Superior progenies are identified on the basis of performance in the trial.

III Season: Selfed seeds from plants with superior test cross progenies are grown population-wise separately and inter-crossed to reconstitute two new populations which will now be called as A’ and B’.

This completes one cycle of reciprocal recurrent selection and additional cycle(s) may be initiated depending upon the variability in the original population and the improvements achieved in the new populations.

**Full-sib Reciprocal Recurrent Selection:** Hallauer and Eberhart (1970) proposed full-sib reciprocal (FSR) recurrent selection for use in prolific maize. Two heterotic populations are taken and S₀ plants in these populations are simultaneously selfed and crossed in inter-population pairs to produce S₁ and full-sib (FS) families, respectively. The FS families are evaluated and S₁ seeds of S₀ plants that have produced superior FS families are used to reconstitute the two populations separately. Hallauer (1973) proposed a modified FSR recurrent selection for use in single eared populations in which S₀ plants are selfed to produce S₁ lines which are crossed to develop FS families.

**Synthetic Variety:** The term synthetic variety has come to be used to designate a variety that is maintained from open-pollinated seed following its synthesis by hybridization in all possible combinations among a number of selected genotypes which have been subjected to combining ability test. The components of a synthetic variety could be inbreds (usually) or mass selected
populations in context of maize. The components are maintained so that the synthetic variety could be reconstituted as and when required.

In maize first inbreds are developed. The inbreds to be used as component lines are selected on the basis of combining ability for which component inbreds are crossed in all possible combinations. The inter-crossed seed is called as S₀ seed. Equal quantity of seed from all crosses is mixed and the mixture is allowed open-pollination in isolation and the seed is harvested. The harvested seed represents S₁ generation. In absence of reconstitution of a synthetic variety at regular intervals, the synthetic variety becomes an open-pollinated variety.

**Composite Variety:** Concept of composite varieties in maize originated in India. Composite varieties in maize are generally derived from varietal crosses in advanced generation. These are usually developed from open-pollinated varieties or other heterozygous populations or germplasm which have usually not been subjected to inbreeding or have not been elaborately evaluated for their combining ability. Usually they involve open-pollinated varieties, synthetics, double crosses, etc. selected for yield performance, maturity, grain characteristics, and resistance to diseases and pests. These composites often show a high degree of heterosis in F₁’s when widely diverged populations are crossed. Advanced generations of such heterotic crosses often show stabilized yields. General combining ability and additive gene action play predominant role in exploitation of these populations (Dhawan, 1985; Singh, 1985). Steps involved in development of maize composites are as follows (Singh, 1980):

i) Screening of diverse germplasm by evaluation at multi-locations/years to identify the source populations having adaptability, desirable agronomic attributes, and resistance to major diseases and serious insect-pests.

ii) Making of all possible crosses among selected superior genotypes or top crossing with a varietal complex of screened base varieties.

iii) Conducting multi-location test with the F₁ and F₂ of the varietal crosses and selection of F₂’s having desirable agronomic features along with least inbreeding depression in F₂.

iv) Evaluation of selected F₂ populations and identification of the best one as practically composites are constituted by compositing seeds of various populations and allowing the mixture to stabilize under open-pollination along with some mild selection in isolation. The constituent entries may not be maintained for reconstituting the
composite. In addition to use of composites as direct cultivars, these can be used as base/source population to develop inbred lines.

**Hybrids**

The term hybrid variety is used to designate F$_1$ populations that are used for commercial plantings. One of the significant achievements in plant breeding has been the exploitation of heterosis through commercial cultivation of hybrid maize. The earliest report on commercial exploitation of heterosis in maize has been by Beal (1980) who estimated heterosis and reported up-to 52% increase in yield of hybrids over OP parents and suggested commercial cultivation of F$_1$ varietal hybrids. However, varietal hybrids could not make good impact. Large scale exploitation of heterosis in maize has to wait for the pioneering work of East (1908, 1909) on inbreeding, Shull (1908) on single crosses, and Jones (1918) on double crosses. Shull and East conducted independent experiments on inbreeding and cross-breeding in maize and observed depression due to inbreeding and restoration of vigour on crossing. Shull (1909) gave a pure-line method of corn breeding which laid the foundation of present day hybrid breeding. The proposed method of Shull (1909) included three steps, namely, (i) large-scale inbreeding to obtain many homozygous or nearly homozygous inbred lines, (ii) testing the selected inbred lines in all possible crosses, and (iii) practical utilization of inbred lines in seed production of single cross hybrids. Shull recognized that the hybrids produced from inbred lines which are homozygous and homogeneous, would be uniform and true to type. Historical perspectives and details of hybrid maize development have been given by Shull (1952) and Hayes (1963).

There were some problems associated with single cross hybrids due to which maize breeders were slow and reluctant in adopting pure-line method. These problems were as follows:

i) Lack of good inbred lines capable of producing single cross hybrids demonstrating significant yield advantage over the available best OP varieties.

ii) Poor germination and planting problems due to small and mis-shaped hybrid seed.

iii) Expensive hybrid seed due to low yield of female inbred parent and substantial proportion of the land devoted to the male inbred parent.
Jones (1918) suggested the use of double cross hybrids to overcome these difficulties associated with the single cross hybrids. The first double cross hybrids in 1920s yielded about 15% higher than the better OP varieties (Duvick, 1999). Now, single cross and double cross hybrids pre-dominate the commercial hybrids world over.

Types of Hybrids:

Conventional Hybrids
These are based on inbred lines. These are of following types:

i) **Single crosses**: a single cross is a hybrid progeny from a cross between two unrelated inbreds = (A x B).

ii) **Three-way crosses**: A three-way cross is the hybrid progeny from a cross between a single cross and an inbred = (A x B) x C.

iii) **Double crosses**: A double cross is the hybrid progeny from a cross between two single crosses = (A x B) x (C x D).

iv) **Modified single crosses**: A modified single cross is the hybrid progeny from a three-way cross which utilizes the progeny from two related inbreds as the seed parent and an unrelated inbred as the pollen parent = (A x A’) x B.

v) **Double modified single crosses**: A double modified single cross is the hybrid progeny from two single crosses, each developed by crossing two related inbreds = (A x A’) x (B x B’).

vi) **Modified three-way hybrids**: A modified three-way hybrid is the progeny of a single cross as female parent and another single cross between two related inbreds = (A x B) x (C x C’).

Non-conventional Hybrids
The concept of non-conventional hybrids has been advocated by CIMMYT for the countries lacking an effective seed production industry. These hybrids are transitional stages between open-pollinated varieties and conventional hybrids. The major types are as follows (Vasal, 1988).

i) **Inter-varietal hybrids**: These are formed by inter-crossing of two varieties. These are approximately equivalent to synthetics/composites.
ii) **Top cross hybrids**: These are inbred x variety hybrids. Following top cross hybrids may be constituted.
   a. Inbred line x variety
   b. Inbred line x experimental hybrid
   c. Inbred line x synthetic variety
   d. Inbred line x family

iii) **Inter-family hybrids**: These hybrids are progeny resulting from the crosses of two families originating from the same population or two different populations.

iv) **Double top cross hybrids**: A double top cross hybrid is the progeny of a single cross and a variety. Such hybrids have been commercialized mostly in India and China.

Single, double and three-way cross hybrids have mostly been commercialized world over. The most striking advantage of single cross hybrids over double and three-way cross hybrids is that single cross breeding is simpler and faster. The probability of identifying two superior inbred lines that combine well and are vigorous is higher than that for three or four inbred lines. It is expected that the best single cross has the highest yield followed by the best three-way cross and the best double cross. In presence of epistasis, it may however, be possible to find out a unique double/three-way cross which may be as good as the best single cross.

Single cross hybrids are homogeneous whereas all other kinds of hybrids are heterogeneous. Being uniform, single cross hybrids may lack somewhat in their adaptability as they have only individual buffering in comparison to other hybrids which are heterogeneous and have individual as well as population buffering (Allard and Bradshaw, 1964). However, Troyer (1996) has demonstrated that stable single cross hybrids can be developed and identified. The uniformity of single cross hybrids has been an important factor in their wide-spread cultivation. The seed production of single cross hybrids has been rather simpler but at the same time, it is costlier. The number of seasons and isolations required for seed production of single cross hybrids is less than that in multi-parent hybrids. On the other hand, the hybrids from non-inbred parents are expected to be more variable but at the same time more stable.

**Development of Inbred Lines**: Inbred lines are developed through self-pollination which is the extreme form of inbreeding and leads to most rapid fixation of genes and attainment of homozygosity. One generation of selfing results in the same level of inbreeding as three
generations of full-sib mating and six generations of half-sib mating. The rate of inbreeding in back-crossing with a homozygous parent is the same as in the selfing. Normally, five selfings are required to develop nearly homozygous inbred lines.

The pedigree method of breeding is the most widely used method to develop inbred lines. Initially the pedigree selection was initiated in the widely adapted OP landraces. Later on, the focus shifted to initiate this process in the F$_2$’s derived from crossing the elite lines that complemented each other for different desirable traits. The base crosses to initiate pedigree method of line development could be complex crosses and back-crosses but the use of single crosses for this purpose is most common. The pedigree method of inbred development is referred to as “standard method” when an open pollinated population is sampled (Sprague and Eberhart, 1977).

In the pedigree method of inbred line development, the seeds of the selected plants are planted as ear-to-row. Phenotypic selection is carried out both among and within progenies. As selfing progresses, the differences among progenies increase and those within progenies decrease. In this process, some breeders prefer to have a smaller sample size and handle a large number of populations rather than sampling a large number of individuals in a smaller number of populations. Emphasis given to different traits during inbred line development in pedigree method has changed over the years. During the earlier years, the lines were selected primarily for hybrid performance but lately there has been increasing focus on vigour and grain yield per se.

Back-cross method is another important method of inbred line development. It is an easy and effective method to handle one or two genes and has been widely used to incorporate resistance to diseases and insect-pests. Normally, three to five back-crosses are made but the number may vary depending upon recovery of the recurrent parent, inheritance of the trait under transfer, selection during back-crossing, genetic similarities between recurrent and donor parents and linkage. With advent of genetically modified organisms, major emphasis is devoted to accelerate back-crosses to transfer the transgenes to elite inbreds. The use of DNA markers has facilitated both the speed and accurate recovery of the recurrent parent and the reduction of linkage drag. Modifications of back-cross method have also been suggested, for
example, convergent improvement developed by Richey (Richey, 1927), which involves back-crossing to both the lines by reciprocal transfer of dominant favourable genes present in parent and lacking in another parent. In this method, two inbreds A and B are crossed. The F₁ is back-crossed with line A followed by selection of desirable traits of line B and F₁ is also back-crossed with line B where selection for desirable traits of line A is made. After about three back-crosses and selection, selfing is done to fix the selected genes. This method is useful for improving such characters such as vigour, resistance to diseases, pests and lodging.

Stadler (1944) devised a scheme of gamete selection which is based on the premise that if superior zygotes occur with a frequency of $p^2$, superior gametes would occur with a frequency of $p$. The procedure involves crossing an elite line with a random sample of pollen of plants from a source population. The resulting F₁ plants and the elite lines are test crossed to a common tester and F₁ plants are also selfed. Test cross progenies are evaluated in a replicated trial. The test crosses of F₁ plants that exceed the elite line by tester are presumed to have obtained a superior gamete from the source population. Superior gametes are recovered as F₂ selfs. Selection and selfing are continued till desirable homozygosity/uniformity is attained. The method of gamete selection is not used as extensively as pedigree and back-cross methods however it is used in some breeding programmes.

The technique of double haploid breeding is also used to develop inbred lines. Although maternal haploidy has been mainly exploited by private sector seed companies in a routine manner, it has not been widely used by public sector organizations. One of the reasons for not using this on wider scale has been due to the fact that there is no scope of phenotypic evaluation and selection as a result of which large number of unselected inbreds are generated to be evaluated for combining ability.

**Maintenance of Inbred Lines:** Inbred lines are generally maintained by a system of self-pollination and growing progenies in ear-to-row fashion in order to observe the changes for various traits. One purpose of developing inbred lines through selfing is to obtain genotypes whose genetic constitution will be maintained over the generations. However, significant
changes have been reported over successive generations in long term inbred line maintenance. These points must be kept in mind while maintaining inbred lines.

**Top-cross Test and Early Testing of Inbred Lines:** Initially, the lines were selected on the basis of their performance in single crosses produced generally in diallel matings and sometimes by factorial matings. However, with increase in number of inbred lines to be tested, it became difficult to make all possible crosses and evaluate the resultant large number of single crosses. Further, performance of inbred lines *per se* did not prove to be useful guide to select lines for combining ability for grain yield. Davis (1927) suggested the use of the top-cross method for preliminary evaluation of a large number of inbred-lines and this has been accepted as a method for preliminary evaluation of new lines for general combining ability followed by their evaluation in single crosses to identify the most productive specific combinations. It is generally accepted that GCA is more important than SCA in unselected lines whereas the reverse is true in previously selected lines.

In earlier days, top-cross evaluation was done in the lines which were in $S_5/S_6$ generations. However, Jenkins (1935) suggested early testing and presented data to show that lines acquired individuality as parents very early during inbreeding and tend to remain fairly stable for combining ability in subsequent generations of inbreeding. Therefore, early testing has been in use rather widely. Top-cross evaluations are done in $S_2$ to $S_4$ but evaluation at $S_3$ is most common.

**Nature of Testers:** On the basis of empirical results, testers from opposite heterotic populations are used. According to Hallauer (1975), the tester should be simple to use and should correctly classify the merits of the lines and maximize genetic gain. Mostly the choice of tester depends upon the breeding objective itself. If the objective is to identify good combiners for a given line or single cross, then appropriate tester is that line or the single cross itself. Initially top-cross tests depended on a broad based tester where the objective was to have preliminary evaluation of the GCA. There have been suggestions to use synthetic tester based on inbred lines in the current use. Narrow genetic base testers have been used to improve the SCA.
Combination of Inbreds in Hybrids and Prediction of Double Cross Performance

**Single crosses:**  \( n \frac{(n-1)}{2} \)

**Three-way crosses:**  \( n \frac{(n-1)(n-2)}{2} \)

**Double crosses:**  \( n \frac{(n-1)(n-2)(n-3)}{8} \)

Where \( n \) is the number of inbred lines.

If there are four inbred lines, A, B, C and D, the performance of double cross hybrids \((A \times B) \times (C \times D)\) can be predicted as follows (Jenkins, 1934).

i) **Based on mean performance of all possible single crosses:**

\[
= (A \times B) + (A \times C) + (A \times D) + (B \times C) + (B \times D) + (C \times D)
\]

\[
\frac{6}{6}
\]

ii) **Based on mean performance of the four non-parental single crosses:**

\[
= (A \times C) + (A \times D) + (B \times C) + (B \times D)
\]

\[
\frac{4}{4}
\]

iii) **Based on mean performance of four lines over a series of single crosses:**

\[
= (A \times E) + (A \times F) + (A \times G) + (A \times H) + (B \times E) + (B \times F) + (B \times G) + (B \times H) + \ldots + (D \times H)
\]

Number of hybrids

iv) **Based on mean performance of top-crosses of the four inbreds:**

\[
= (A \times \text{variety}) + (B \times \text{variety}) + (C \times \text{variety}) + (D \times \text{variety})
\]

\[
\frac{4}{4}
\]

Jenkins evaluated different prediction methods and reported that the most accurate method for predicting the doubled cross was based on the mean performance of non-parental single crosses of the double cross. Since then, this has been most widely used method.

**Hybrid Seed Production**

i) **Hand Detasselling:** This is the common method of producing hybrid seed in tropical countries particularly the Indian sub-continent. In USA, detasselling and cytoplasmic male sterility both are used. In detasselling system, female and male parents are grown alternately in a ratio of 6 rows of female and 2 rows of male. The female rows are detasselled before inflorescence sheds pollen and seed produced on these detasselled plants is the hybrid seed.
ii) Use of Cytoplasmic-Genetic Male Sterility: This approach is usually followed in combination with detasselling method in USA. General genetical system is as follows:

a. Maintenance of cytoplasmic male sterile line-A

\[
\text{S-rfrf} \quad \times \quad \text{F-rfrf} \\
\text{Male sterile line-A} \quad \downarrow \quad \text{Male fertile line-B} \\
\text{S-rfrf} \\
\text{Male fertile line-A}
\]

b. Single cross hybrid

\[
\text{S-rfrf} \quad \times \quad \text{F-Rfrf} \\
\text{Male sterile line-A} \quad \downarrow \quad \text{Male fertile line-C} \\
\text{F-Rfrf} \\
\text{Male fertile}
\]

\[S = \text{Sterile cytoplasm} \]
\[F = \text{Fertile cytoplasm} \]
\[Rf = \text{Fertility restorer gene}\]

In the above programme for producing hybrid seed of A x C, A and C could be planted in alternate rows and seed set on A without detasselling will be hybrid seed and will be male fertile due to restorer gene Rf. In maize three types of cytoplasm have been identified on the basis of fertility restoration when tested against a common set of inbred lines. These are cms-T, cms-C and cms-S. Cytoplasm cms-T has been found to be susceptible to race T of southern corn leaf blight.
Seed Production of Maize - General Principles and Practices

The history of agricultural progress from the early days of man has been the history of seeds of new crops and crop varieties brought under cultivation. In the early days it was achieved through the cultivation of indigenous but useful plants and those taken through introductions. Selection of superior types from cultivated plants constituted the next stage of progress. In the course of time many useful selections were made and there was gradual but steady progress in crop improvement. Later, through the use of well-known techniques of selection, hybridization and polyploidization, the scientists made available many new and better varieties. However, the pace of progress remained slow for a long time. It was only during the mid-sixties that a revolution took place in our concept of yield potential of the major cereals and millets due to the discovery of morphological factors such as the dwarfing gene influence and the response of self-fertilized crops like rice and wheat to increased doses of fertilizers. Similarly, in the case of cross-fertilized crops, the exploitation of hybrid vigor became the basis for making significant advances in yield. The introduction, development and release of dwarf varieties of rice and wheat and hybrids of maize, have helped to raise the hopes and expectations as regards yield possibilities and consequently have stimulated interest among the farming community in a new agronomy revolving around the cultivation of high yielding varieties.

Among the inputs used by farmers, seed is the cheapest. It is a basic input and forms only a small part of the total cultivation expenses. Yet, without good seed the investment on fertilizer, water, pesticides and other inputs will not pay the required dividends. The indifference towards quality seed which hitherto prevailed should, cause no surprise. It epitomized the more general indifference towards scientific agriculture. Since it is a biological industry, good agriculture depends upon good seed and vice versa. One can’t exist or advance without the other. The pace of progress in food production, therefore, will largely depend upon the speed with which we are able to multiply and distribute/market good quality seeds of high yielding varieties.

Difference Between Scientifically Produced Seed and the Grain (Used as Seed)

The seed, when scientifically produced (such as under seed certification) is distinctly superior in terms of seed quality, namely, the improved variety, varietal purity, freedom from admixtures of
weeds and other crop seeds, seed health, high germination and vigour, seed treatment and safe moisture content etc. Its quality and thus expected performance is known. A grain, on the other hand, includes cereals and pulses, meant for human consumption. The major differences between scientifically produced seed and the grain (when used as seed) are listed in Table 4.

**Table 4. Difference between seed and grain used as seed**

<table>
<thead>
<tr>
<th>S.N.</th>
<th>Scientifically produced seed</th>
<th>Grain (used as seed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>It is the result of well planned seed production programme.</td>
<td>It is the part of commercial produce, saved for sowing/planting purposes.</td>
</tr>
<tr>
<td>2.</td>
<td>It is the result of sound scientific knowledge, organized effort, and investment on processing, storage and marketing facilities.</td>
<td>No such knowledge or effort is required.</td>
</tr>
<tr>
<td>3.</td>
<td>The pedigree of the seed is ensured. It can be related to the initial breeder seed.</td>
<td>Its varietal purity is unknown.</td>
</tr>
<tr>
<td>4.</td>
<td>During production effort is made to rogue out off types, diseased plants, objectionable weeds and other crop plants at appropriate stages of crop growth which ensures satisfactory seed purity and health.</td>
<td>No such effort is made. Hence, the purity and health status of the produce may be inferior.</td>
</tr>
<tr>
<td>5.</td>
<td>The seed is scientifically processed, treated and packed and labeled with proper lot identity.</td>
<td>The grain used as seed may be manually cleaned. In some cases, prior to sowing it may also be treated. This is not labeled.</td>
</tr>
<tr>
<td>6.</td>
<td>The seed is tested for planting quality, namely, germination, purity, admixture of weed seeds and other crop seeds, seed health and seed moisture content.</td>
<td>Routine seed testing is not done.</td>
</tr>
<tr>
<td>7.</td>
<td>The seed quality is usually supervised and monitored by an independent agency not related with production (Seed Certification Agency).</td>
<td>There is no quality control.</td>
</tr>
<tr>
<td>8.</td>
<td>The seed has to essentially meet the “Quality Standards”. The quality is therefore well known.</td>
<td>No such standards apply here. The quality is non-descript and not known.</td>
</tr>
<tr>
<td>9.</td>
<td>The labels/certification tags on the seed containers serves as quality marks.</td>
<td>No such label/certification is required.</td>
</tr>
</tbody>
</table>

**General Seed Certification Standards**

The general seed production principles and practices must be in tune with conformity with international guidelines with minor changes as per local needs. For this purpose, here the seed production principles and practices as accepted and incorporated into seed laws and regulations
by India are reproduced. These are based on general guidelines as per requirements of International Seed Testing Association and in harmony with international obligations. The General Seed Certification Standards are applicable to all crops which are eligible for certification, and with field and seed standards for the individual crops, shall constitute the Minimum Seed Certification Standards. The word ‘Seed’ or ‘Seeds’ as used in these standards shall include all propagating materials.

**Purpose of Seed Certification**

The purpose of seed certification is to maintain and make available to the public, through certification, high quality seeds and propagating materials of notified kinds and varieties so grown and distributed as to ensure genetic identity and genetic purity. Seed certification is also designed to achieve prescribed standards.

**Certification Agency**

Certification shall be conducted by the Certification Agency notified under the Seeds Acts of a particular country. To regulate the seed sector, the Govt. of DPRK has enacted a new Crop Seed Law (Seed Act) which supersedes Order No 44. It has 6 Chapters and 53 Articles dealing with registration and release of plant varieties, breeder’s right, production of seeds of various classes, responsibility of seed production and quality control, export and import of seed and disposal of leftover seed, if any (Annexure II).

**Certified Seed Producer**

Certified seed producer means a person/organization who grows or distributes certified seed in accordance with the procedures and standards of the certification.

**Eligibility Requirements for Certification of Crop Varieties**

Seed of only those varieties which are notified under the Seeds Acts/Rules/Regulation shall be eligible for certification.

**Classes and Sources of Seed**
**Breeder Seed**

Breeder seed is seed or vegetative propagating material directly controlled by the originating or sponsoring plant breeder of the breeding programme or institution and/or seed whose production is personally supervised by a qualified plant breeder and which provides the source for the initial and recurring increase of Foundation seed.

Breeder seed shall be genetically so pure as to guarantee that in the subsequent generation i.e. certified Foundation seed class shall conform to the prescribed standards of genetic purity. The other quality factors of Breeder seed such as physical purity, inert matter, germination etc. shall be indicated on the label on actual basis. The Breeder seed shall be packed and supplied by the breeders in the form and manner prescribed.

**Foundation Seed**

Foundation seed is the progeny of breeder seed grown under supervision of certifying agency to meet the requirements of genetic and physical purity as per prescribed field and seed standards.

**Certified Seed**

Certified seed shall be the seed certified by Certification Agency notified under certain Sections of the Seeds Act or seed certified by any Certification Agency established in any foreign country provided the Certification Agency has been reorganized by the Central Government through notification in the Official Gazette. Certified seed shall consist of two classes, namely, Foundation and Certified seed and each class shall conform to the following description:

1. Certified Foundation seed shall be the progeny of Breeder seed, or be produced from Foundation seed which can be clearly traced to Breeder seed. Thus, Foundation seed can even be produced from Foundation seed. During the production of certified Foundation seed, the following guidelines shall be observed:

   (a) Certified Foundation seed produced directly from Breeder seed shall be designated as Foundation seed stage-I;
(b) Certified Foundation seed produced from Foundation seed stage-I shall be designated as Foundation seed stage-II;

(c) Certified Foundation seed stage-II will not be used for further increase of Foundation seed and shall be used only for production of Certified seed class;

(d) Minimum Seed Certification Standards shall be the same for both Foundation seed stage-I and II unless otherwise prescribed;

(e) Certification tag shall be of white colour for both Foundation seed stage-I and II and shall contain the information as to its stage;

(f) Production of Foundation seed stage-II shall ordinarily be adopted in respect of such crop varieties provided, when it is expressly felt by the Certification Agency that Breeder seed is in short supply;

(g) Production of Foundation seed stage-II may be adopted for the following group of crops:

- vegetatively propagated crops;
- apomictically reproduced crops;
- self-pollinated crops;
- often cross-pollinated and cross-pollinated crops, these being gene – pools should not lose their genetic identity and purity if measures to safeguard the same are adequately taken;
- composites and synthetics;
- parental line increase of hybrids.

2. Production of Foundation seed stage-I and II shall be supervised and approved by the Certification Agency and be so handled as to maintain specific genetic identity and genetic purity and shall be required to conform to certification standards specified for the crop/variety being certified.

3. (a) Certified seed shall be the progeny of Foundation seed and its production shall be so handled as to maintain specific genetic identity and purity according to standards prescribed for the crop being certified;
(b) Certified seed may be the progeny of Certified seed provided this reproduction does not exceed three generations beyond Foundation seed stage-I and
- it is determined by the Certification Agency that genetic identity and genetic purity will not be significantly altered;
- and when the Certification Agency is satisfied that there is genuine shortage of Foundation seed despite all the reasonable efforts made by the seed producer.

(c) Certification tag shall be of blue colour (shade ISI No. 104 AZURE BLUE) for Certified seed class.

(d) Certified seed produced from Certified seed shall not be eligible for further seed increase under certification. Certification tags for such production which is not eligible for further seed increase under certification shall be super-scribed with, “not eligible for further seed increase under certification”.

**Phases of Seed Certification**

Certification shall be completed in six broad phases listed as under:

(a) receipt and scrutiny of application;
(b) verification of seed source, class and other requirements of the seed used for raising the seed crop;
(c) field inspections to verify conformity to the prescribed field standards;
(d) supervision at post-harvest stages including processing and packing;
(e) seed sampling and analysis, including genetic purity test and/or seed health test, if any, in order to verify conformity to the prescribed standards; and
(f) grant of certificate and certification tags, tagging and sealing.

**Establishing Source of Seed**

The individual intending to produce seed under certification shall submit to the Certification Agency, one or more relevant evidence such as certification tags, seals, labels, seed containers, purchase records, sale records etc., as may be demanded by the Certification Agency during submission of the application, its scrutiny and/or during first inspection of the seed crop, in order
to confirm if the seed used for raising the crop has been obtained from the source approved by it and conforms to the provisions contained in Acts/Rules. This requirement also applies to both parents in seed production involving two parental lines.

**Field Area for Certification**

There is no minimum or maximum limit for the area offered by a person for certification, provided the certified seed production meets all the prescribed requirements.

**Unit of Certification**

For the purpose of field inspection, the entire area planted under seed production by an individual shall constitute one unit provided:

(a) it is all under one variety;
(b) it does not exceed ten hectares;
(c) it is not divided into fields separated by more than fifty meters between them;
(d) it is planted with or is meant to produce seed belonging to the same class and stage in the generation chain;
(e) the crop over the entire area is more or less of the same stage of growth so that observations made are representative of the entire crop;
(f) the total area planted, by and large, corresponds to the quantity of seed reported to have been used; and the Certification Agency’s permission had been obtained to sow a larger area by economizing on seed rate; if that is the case;
(g) raised strictly as a single crop and never as mixed;
(h) not so heavily and uniformly lodged that more than one third of the plant population is trailing on the ground leaving no scope for it to stand up again thus making it impossible for the Certification Agency to inspect the seed crop at the appropriate growth stage in the prescribed manner;
(i) as far as possible, so maintained as to show adequate evidence of good crop husbandry thereby improving the reputation for certified seeds; and
(j) not grown as inter, companion or ratoon crop unless otherwise specified.
INBRED LINES

I. Application and Amplification of General Seed Certification Standards

A. The General Seed Certification Standards are basic and, together with the following specific standards constitute the standards for certification of the seeds of maize inbred lines.

B. The General Standards are amplified as follows to apply specifically to the inbred lines of maize.

1. Eligibility Requirements for Certification

   An inbred line to be eligible for certification must be from a source such that its identity may be assured and approved by the Certification Agency.

2. Classes and Sources of Seed

   An inbred line shall be a relatively true breeding strain.

3. Seed House or Bin Inspection

   The inbred lines shall be ear-inspected after maturity by the Certification Agency.

II. Land Requirements

   Land to be used for inbred line increase of maize shall be free of volunteer plants.

III. Field Inspection

   A minimum of four inspections shall be made in such a way that one is done before flowering and the remaining three during flowering and maturity.

IV. Field Standards

   A. General Requirements
1. Isolation

(a) Seed fields shall be isolated from the contaminants shown in column 1 of the Table below (Table 5) by the distances specified in column 2 of the said Table:

**Table 5. Isolation distance for seed production of maize inbreds**

<table>
<thead>
<tr>
<th>Contaminants</th>
<th>Minimum distance (meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fields of any maize with same kernel colour and texture</td>
<td>400</td>
</tr>
<tr>
<td>Fields of any maize with different kernel colour and texture, and teosinte</td>
<td>600</td>
</tr>
<tr>
<td>Fields of the same inbred line not conforming to varietal purity requirements for certification</td>
<td>400</td>
</tr>
</tbody>
</table>

(b) Differential blooming dates will be permitted for modifying isolation distances with any type of maize provided 5.0% or more of the plants in the seed parent do not have receptive silks when more than 0.20% of plants in the adjacent field(s) within the prescribed isolation distance are shedding pollen.

B. Specific Requirements

The specific requirements shall be as given in Table 6.

**Table 6. Maximum permitted off types in the seed production field of maize inbreds**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Maximum permitted (%)*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Off type plants that have shed or are shedding pollen when 5.0% or more of the plants in the seed field have apparently receptive silks</strong></td>
<td>0.20</td>
</tr>
</tbody>
</table>
**Sucker tassels, portions of tassels, and tassels on main plants will be counted as shedding pollen only when two inches or more of the centre spike, the side branches, or a combination of the two have the anthers exerted from the glumes and are shedding pollen.

V. **Seed Standards**

A. Seed ears inspected after harvest shall not contain in excess of 0.20% of off type ears including ears with off-coloured kernels. Other factors and the prescribed standards shall be as given in Table 7.

**Table 7. Seed standards in maize inbred line seeds**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pure seed (minimum)</td>
<td>98.0%</td>
</tr>
<tr>
<td>Inert matter (maximum)</td>
<td>2.0%</td>
</tr>
<tr>
<td>Other crop seeds (maximum)</td>
<td>5/kg</td>
</tr>
<tr>
<td>Other distinguishable varieties based on kernel colour and texture (maximum)</td>
<td>5/kg</td>
</tr>
<tr>
<td>Weed seeds (maximum)</td>
<td>None</td>
</tr>
<tr>
<td>Germination (minimum)</td>
<td>80%</td>
</tr>
<tr>
<td>Moisture (maximum)</td>
<td>12.0%</td>
</tr>
<tr>
<td>For vapour-proof containers (maximum)</td>
<td>8.0%</td>
</tr>
</tbody>
</table>

B. **Shelling**

Shelling of the seed ears will be made after obtaining approval from the Certification Agency.

**FOUNDATION SEED**

**SINGLE CROSSES**

I. **Application and Amplification of General Seed Certification Standards**

A. The General Seed Certification Standards are basic and, together with the following specific standards constitute the standards for certification of the seeds of maize foundation single crosses.
B. The General Standards are amplified as follows to apply specifically to the foundation single crosses of maize

1. **Eligibility Requirements for Certification**

   A foundation single cross to be eligible for certification must be produced from two approved inbred lines, the sources of which shall assure their identity and the inbred lines should be approved by the Certification Agency.

2. **Classes and Sources of Seed**

   A foundation single cross shall consist of the first generation hybrid resulting from the controlled crossing of two approved inbred lines. Such foundation single cross shall be used in the production of double, three-way, top or double top crosses.

3. **Seed House or Bin Inspection**

   The foundation single crosses shall be ear-inspected after maturity by the Certification Agency.

II. **Land Requirements**

   Land to be used for seed production of maize single crosses shall be free of volunteer plants.

III. **Field Inspection**

   A minimum of four inspections shall be made in such a way that one is done before flowering and the remaining three during flowering and maturity.

IV. **Field Standards**

   A. **General Requirements**

      1. **Isolation**
(a) Seed fields shall be isolated from the contaminants shown in column 1 of the Table 8 below by the distances specified in column 2 of the said Table:

### Table 8. Isolation distance in seed production of single crosses of maize

<table>
<thead>
<tr>
<th>Contaminants</th>
<th>Minimum distance (meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fields of any maize with same kernel colour and texture</td>
<td>400</td>
</tr>
<tr>
<td>Fields of any maize with different kernel colour and texture, and teosinte</td>
<td>600</td>
</tr>
<tr>
<td>Fields of the same single cross (code designation) not conforming to varietal purity requirements for certification</td>
<td>400</td>
</tr>
<tr>
<td>Fields of the other single crosses having common male parent and conforming to varietal purity requirements for certification</td>
<td>5</td>
</tr>
<tr>
<td>Fields of the other single crosses having common male parent and not conforming to varietal purity requirements for certification</td>
<td>400</td>
</tr>
</tbody>
</table>

(b) Differential blooming dates are permitted for modifying isolation distances, provided 5.0% or more of the plants in the seed parent do not have receptive silks when more than 0.20% of plants in the adjacent field(s) within the prescribed isolation distance are shedding pollen.

### B. Specific Requirements

Specific requirements shall be as given in Table 9.

### Table 9. Specific requirements in field of seed production of single crosses of maize
<table>
<thead>
<tr>
<th>Factor</th>
<th>Maximum permitted (%)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Off-type plants that have shed or are shedding pollen in male parent at any one inspection during flowering when 5.0% or more of the plants in the seed field have apparently receptive silks</td>
<td>0.20</td>
</tr>
<tr>
<td>Tassels of the plants that have shed or shedding pollen in seed parent at any one inspection during flowering when 5.0% or more of the plants in the seed parent have apparently receptive silks</td>
<td>0.50</td>
</tr>
<tr>
<td>Total of pollen shedding tassels including tassels that have shed pollens for all three inspections conducted during flowering on different dates</td>
<td>1.0</td>
</tr>
<tr>
<td>Off-types plants in seed parent at final inspection</td>
<td>0.20</td>
</tr>
</tbody>
</table>

*Sucker tassels, portions of tassels, and tassels on main plants shall be counted as shedding pollen only when two inches or more of the centre spike, the side branches, or a combination of the two have the anthers exerted from the glumes and are shedding pollen.

V. **Seed Standards**

A. Seed ears inspected after harvest shall not contain in excess of 0.20% of off-type ears including ears with off-coloured kernels. Other factors shall be as given in Table 10.

**Table 10. Seed standards in seed of single crosses of maize**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pure seed (minimum)</td>
<td>98.0%</td>
</tr>
<tr>
<td>Inert matter (maximum)</td>
<td>2.0%</td>
</tr>
<tr>
<td>Other crop seeds (maximum)</td>
<td>5/kg</td>
</tr>
<tr>
<td>Other distinguishable varieties based on kernel colour and texture (maximum)</td>
<td>5/kg</td>
</tr>
<tr>
<td>Weed seeds (maximum)</td>
<td>None</td>
</tr>
<tr>
<td>----------------------</td>
<td>------</td>
</tr>
<tr>
<td>Germination (minimum)</td>
<td>80%</td>
</tr>
<tr>
<td>Moisture (maximum)</td>
<td>12.0%</td>
</tr>
<tr>
<td>For vapour-proof containers (maximum)</td>
<td>8.0%</td>
</tr>
</tbody>
</table>

**B. Shelling**

Shelling of the seed ears will be made after obtaining approval from the Certification Agency.
MAIZE HYBRIDS
SWEET CORN HYBRIDS

I. Application and Amplification of General Seed Certification Standards

A. The General Seed Certification Standards are basic and, together with the following specific standards constitute the standards for certification of hybrid maize seed.

B. The General Standards are amplified as follows to apply specifically to the hybrids of maize.

1. Eligibility Requirements for Certification

   A hybrid is one to be planted for any use except seed production. It may be any one of the various kinds of hybrids like, single crosses, double crosses, three-way crosses, top crosses, double top crosses, etc.

2. Classes and Sources of Seed

   (a) Only the class ‘certified’ shall be recognized.
   
   (b) A hybrid to be certified must be produced from certified foundation seed or seed stocks approved by the Certification Agency.

3. Seed House or Bin Inspection

   Maize hybrids shall be ear-inspected after maturity by the Certification Agency.

II. Land Requirements

   Land to be used for seed production of maize hybrids shall be free of volunteer plants.
III. Field Inspection

A minimum of four inspections shall be made in such a way that one is made before flowering and the remaining three during flowering and maturity.

IV. Field Standards

A. General Requirements

1. Isolation

(a) A specific hybrid of maize shall be isolated from the contaminants shown in column 1 of the Table 11 below by the distances specified in column 2 of the said Table:

Table 11. Isolation distance for maize hybrids

<table>
<thead>
<tr>
<th>Contaminants</th>
<th>Minimum distance (meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>*Fields of any maize with same kernel colour and texture</td>
<td>200</td>
</tr>
<tr>
<td>Fields of any maize with different kernel colour and texture, and teosinte</td>
<td>300</td>
</tr>
<tr>
<td>*Fields of the same hybrid (code designation) not conforming to varietal purity requirements for certification</td>
<td>200</td>
</tr>
<tr>
<td>*Fields of the other hybrids having common male parent and conforming to varietal purity requirements for certification</td>
<td>5</td>
</tr>
<tr>
<td>*Fields of the other hybrids having common male parent and not conforming to varietal purity requirements for certification</td>
<td>200</td>
</tr>
</tbody>
</table>
Distances less than 200 meters may be modified by planting border rows of male parent, if the kernel colour and texture of the contaminant are the same as that of the seed parent. The number of border rows to be planted all around the seed field to modify isolation distances less than 200 meters shall be determined by the size of the field and its distance from the contaminant as shown in the Table 12 below:

**Table 12. Number of border rows in relation to isolation distance to prevent out-crossing from undesirable types in hybrid seed production of maize**

<table>
<thead>
<tr>
<th>More than</th>
<th>4</th>
<th>6</th>
<th>8</th>
<th>10</th>
<th>12</th>
<th>14</th>
<th>16</th>
<th>Or over</th>
</tr>
</thead>
<tbody>
<tr>
<td>upto:</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>10</td>
<td>12</td>
<td>14</td>
<td>16</td>
<td></td>
</tr>
</tbody>
</table>

And the distance (in meters) of the seed parent from other maize with kernel colour and texture the same as that of the seed parent is at least:

| 200.0  | 195.0 | 190.0 | 185.0 | 180.0 | 175.0 | 170.0 | 165.0 | 1    |
| 187.5  | 182.5 | 177.5 | 172.5 | 167.5 | 162.5 | 157.5 | 152.5 | 2    |
| 175.0  | 170.0 | 165.0 | 160.0 | 155.0 | 150.0 | 145.0 | 140.0 | 3    |
| 162.5  | 157.5 | 152.5 | 147.5 | 142.5 | 137.5 | 132.5 | 127.5 | 4    |
| 150.0  | 145.0 | 140.0 | 135.0 | 130.0 | 125.0 | 120.0 | 115.0 | 5    |
| 137.5  | 132.5 | 127.5 | 122.5 | 117.5 | 112.5 | 107.5 | 102.5 | 6    |
| 125.0  | 120.0 | 115.0 | 110.0 | 105.0 | 100.0 | 95.0  | 90.0  | 7    |
| 112.5  | 107.5 | 102.5 | 97.5  | 92.0  | 87.5  | 82.5  | 77.5  | 8    |
| 100.0  | 95.0  | 90.0  | 85.0  | 80.0  | 75.0  | 70.0  | 65.0  | 9    |
| 87.5   | 82.5  | 77.5  | 72.5  | 67.5  | 62.5  | 57.5  | 52.5  | 10   |
| 75.0   | 70.0  | 65.0  | 60.0  | 55.0  | 50.0  | 45.0  | 40.0  | 11   |
| 62.5   | 57.5  | 52.5  | 47.5  | 42.5  | 37.5  | 32.5  | 27.5  | 12   |
| 50.0   | 45.0  | 40.0  | 35.0  | 30.0  | 25.0  | 20.0  | 15.0  | 13   |
This table applies to all sides of the seed field exposed to contamination, whether located directly opposite or diagonally.

(b) Border rows must be planted in the seed field or adjacent to it, but in no case separated by more than five meters from the seed field.

(c) Border rows must be planted at the same time as the rest of the seed field so that the flowering time of both is the same; i.e., border rows should be shedding pollen when silks in the seed parent are receptive.

(d) Border rows must be planted all along and opposite to the contaminating maize.

(e) There should be a reasonable stand of border rows, i.e., there must not be gaps in the border rows. Border rows must have been planted using the seed rate and spacing adopted for the seed crop.

(f) The area planted under border rows is taken into consideration while modifying the isolation distance.

(g) Seed fields having diagonal exposure to contaminating fields are to be planted with border rows in both directions of exposure.

(h) If two hybrid seed fields with different pollinator parents are within the isolation distance of one another, border rows are necessary for each of them in order to avoid contamination of the respective seed parent.

(i) Natural barriers such as tall thick trees, buildings etc., between the seed and contaminating fields shall not be a substitute to border rows.

(j) Border rows must be planted with seed used for planting male rows in the seed field. Seed saved from male rows of the previous production of the same cross cannot be used for planting of border rows or for planting within the isolation distance.

(k) The isolation distance continues to be 300 meters if the kernel colour or texture of the contaminating maize is different from that of the seed parent or if the contaminating field is planted with sweet corn, popcorn or teosinte. In this case, modification of isolation distance by planting border rows will not be permitted.
Differential blooming dates are permitted for modifying isolation distances, provided 5.0% or more of the seed parent plants do not have receptive silks when more than 0.050% of plants in the field(s) within the isolation distance are shedding pollen.

B. Specific Requirements

The specific requirements for hybrid seed production of maize shall be as given in Table 13.

**Table 13. Specific requirements in the hybrid seed production of maize field**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Maximum permitted (%)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Off type plants that have shed or are shedding pollen in male parent at any one inspection during flowering when 5.0% or more of the plants in the seed field have receptive silks</td>
<td>0.50</td>
</tr>
<tr>
<td>Tassels of the plants that have shed or shedding pollen in seed parent at any one inspection during flowering when 5.0% or more of the plants in the seed parent have receptive silks</td>
<td>1.00</td>
</tr>
<tr>
<td>Total of pollen shedding tassels including tassels that have shed pollens for all three inspections conducted during flowering on different dates</td>
<td>2.0</td>
</tr>
<tr>
<td>Off-types plants in seed parent at final inspection</td>
<td>0.50</td>
</tr>
</tbody>
</table>

*Sucker tassels, portions of tassels, and tassels on main plants shall be counted as shedding pollen only when two inches or more of the centre spike, the side branches, or a combination of the two have the anthers exerted from the glumes and are shedding pollen.

V. **Seed Standards**
A. Seed ears inspected after harvest shall not contain in excess of 0.50% of off type ears including ears with off-coloured kernels. Other factors are given in Table 14.

Table 14. Seed standards in maize hybrid seed production

<table>
<thead>
<tr>
<th>Factor</th>
<th>Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pure seed (minimum)</td>
<td>98.0%</td>
</tr>
<tr>
<td>Inert matter (maximum)</td>
<td>2.0%</td>
</tr>
<tr>
<td>Other crop seeds (maximum)</td>
<td>10/kg</td>
</tr>
<tr>
<td>Other distinguishable varieties based on kernel colour and texture (maximum)</td>
<td>10/kg</td>
</tr>
<tr>
<td>Weed seeds (maximum)</td>
<td>None</td>
</tr>
<tr>
<td>Germination (minimum)</td>
<td>80%</td>
</tr>
<tr>
<td>Moisture (maximum)</td>
<td>12.0%</td>
</tr>
<tr>
<td>For vapour-proof containers (maximum)</td>
<td>8.0%</td>
</tr>
</tbody>
</table>

B. Shelling

Shelling of the seed ears will be made after obtaining approval from the Certification Agency.
COMPOSITE, SYNTHETICS
AND OPEN-POLLINATED VARIETIES

I. Application and Amplification of General Seed Certification Standards

A. The General Seed Certification Standards are basic and, together with the following specific standards constitute the standards for certification of the seeds of composites, synthetics and open-pollinated varieties of maize.

B. The General Standards are amplified as follows to apply specifically to composites, synthetics and open-pollinated varieties of maize.

1. Eligibility Requirements for Certification

A composite or a synthetic or an open-pollinated variety to be eligible for certification must be from such a source that its identity may be assured and approved by the Certification Agency.

2. Seed House or Bin Inspection

Composites, synthetics and open-pollinated varieties of maize shall be ear-inspected after maturity by the Certification Agency.

II. Land Requirements

Land to be used for seed production of maize composites, synthetics and open-pollinated varieties shall be free of volunteer plants.

III. Field Inspection

A minimum of four inspections shall be made in such a way that one is done before flowering and the remaining three during flowering and maturity.

IV. Field Standards

A. General Requirements
1. **Isolation**

The seed fields shall be isolated from the contaminants shown in column 1 of the Table below by the distances specified in column 2 and 3 of the said Table 15.

**Table 15. Isolation distance in maize synthetics/composites seed production field**

<table>
<thead>
<tr>
<th>Contaminants</th>
<th>Minimum distance (meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Foundation</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Fields of other varieties</td>
<td>400</td>
</tr>
<tr>
<td>Fields of the same variety not conforming to varietal purity requirements for certification and teosinte</td>
<td>400</td>
</tr>
</tbody>
</table>

B. **Specific Requirements**

Specific requirements are as given in Table 16.

**Table 16. Specific requirements for seed production of maize synthetics/composites in the field**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Maximum permitted (%)*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Foundation</td>
</tr>
<tr>
<td>Off-types plants that have shed or are shedding pollen at any one inspection during flowering when 5.0% or more of the plants in the seed field have receptive silks.</td>
<td>1.0</td>
</tr>
</tbody>
</table>

V. **Seed Standards**
A. Seed ears inspected after harvest shall not contain in excess of 1.0% of off-type ears including the ears with off-coloured kernels. Seed standards for maize synthetics/composites are as given in Table 17.

Table 17. Seed standards for maize synthetics/composites

<table>
<thead>
<tr>
<th>Factor</th>
<th>Standards for each class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Foundation</td>
</tr>
<tr>
<td>Pure seed (minimum)</td>
<td>98.0%</td>
</tr>
<tr>
<td>Inert matter (maximum)</td>
<td>2.0%</td>
</tr>
<tr>
<td>Other crop seeds (maximum)</td>
<td>5/kg</td>
</tr>
<tr>
<td>Other distinguishable varieties based on kernel colour and texture</td>
<td>10/kg</td>
</tr>
<tr>
<td>(maximum)</td>
<td></td>
</tr>
<tr>
<td>Weed seeds (maximum)</td>
<td>None</td>
</tr>
<tr>
<td>Germination (minimum)</td>
<td>80%</td>
</tr>
<tr>
<td>Moisture (maximum)</td>
<td>12.0%</td>
</tr>
<tr>
<td>For vapour-proof containers (maximum)</td>
<td>8.0%</td>
</tr>
</tbody>
</table>

B. Shelling

Shelling of the seed ears is to be done after obtaining approval from the Certification Agency.
Seed Production of Maize in DPRK, Seed Regulations, Issues and Recommendations

Current Status
Assuming seed rate of 100 kg/ha and total maize area of 503,000 ha in the DPRK, the total certified seed requirement of maize comes to 50,300 tons. The current seed production system in the Democratic People Republic of Korea (DPRK) needs up-grading of seed production and certification organizations essential for a successful seed programme. All essential components namely: plant breeding, varietal assessment and maintenance, seed production, processing, testing and distribution exist and are functional. The production of nucleus/breeder and foundation/certified seed relies on the Academy of Agricultural Sciences (AAS) and cooperative foundation and certified seed farms, both are involved in an integrated seed production chain. Academy of Agricultural Sciences (AAS) produces nucleus and breeder seeds in small quantities and breeder seed is multiplied on 25 cooperative foundation seed farms to produce foundation seed. Foundation seeds are then multiplied at 240 cooperative certified seed farms for the production of certified seed. Certified seeds are usually those destined for commercial distribution to large numbers of farmers on a regional and national basis for the purpose of commercial crop production on more than 3,500 cooperative farms.

Under a typical generation chain breeder seed is multiplied from nucleus seed. However, it is observed that sometimes breeder seed is multiplied in bulk from breeder seed itself for several generations. Similarly foundation seed is multiplied from breeder seed but instances are there when it is multiplied from foundation seed itself till seed physically looks fine and conforms to purity and varietal characteristics. The practice of bulk increase of breeder seed and unlimited multiplication cycles of foundation seed without going back to breeder seed may seriously affect the quality of seed produced and this practice should be discouraged. Standard procedures for breeder seed production require to be laid down for maize and multiplication of foundation seed should be restricted to only two generations only i.e., foundation seed stage-I and foundation seed stage-II as specified in the certification standards in most of the countries.

For ensuring the quality of seeds there is a separate Central Seed Inspection Centre in Pyongyang. NGOs like Swiss Agency for Development and Cooperation (SDC) and Welt Hunger Hilfe are helping to develop seed quality laboratory at the centre. The centre has more than 46 experts
working in different branches. It has 10 provincial seed inspection centres to deal with quality control of seed in the field. Both central and provincial units are fairly large and employ research, administrative and support staff in good numbers.

To regulate seed sector, the Govt. of DPRK has enacted a new Crop Seed Law (Seeds Act) which superseded Order No 44. It has 6 Chapters and 53 Articles (Annexure II) dealing with registration and release of plant varieties, breeder’s right, production of seeds of various classes, responsibility of seed production and quality control, export and import of seed and disposal of leftover seed, if any. The enforcement of the Seeds Act will certainly lead to the upgrading of the quality of seeds. The Seeds Act will, however, help only to the extent it is implemented in a proper spirit and availability of essential infrastructure needed to enforce the provisions of the Act. If Seeds Act is to be implemented in the spirit it has been framed, it is necessary to have required number of qualified officials, and necessary production and quality control facilities. These facilities must have good farm and seed processing equipment and modern testing facilities for registration of plant varieties besides, well equipped seed testing laboratories capable of carrying out various tests following international standards. The adherence to international rules and regulations related to seed quality and plot inspection is a fundamental requirement to implement Seeds Act provisions especially relating to export and import of seed and granting Plant Breeders’ Right. Therefore, centre should strive for getting its laboratory accredited by International Seed Testing Association (ISTA).

The production of various classes of seed relies on the research academy and cooperative seed farms, both involved in an integrated seed production chain. There are three recognized classes of seed under seed-generation control system i.e. Breeder Seed (BS), Foundation Seed (FS) and Certified Seed (CS). To ensure quality and quantity of seed it is necessary that generation chain is followed without any significant deviation by all concerned.

Seed production is a long drawn continuous process and seeds cannot be produced over-night. Therefore, to maintain a continuous flow of seed a strong coordination between Academy of Agricultural Sciences (AAS) and seed farms is necessary to avoid cycle of shortages or glut and to ensure availability of required seed.
Breeder seed forms the basis of all further seed production arrangements. It is the availability of pure breeder seed of a variety through which the varietal improvement research reaches to the public which in turn leads to increase in agricultural productivity and improvement in the economy. Therefore, AAS should pay utmost attention to maintain the quality of breeder seed.

It is readily and conveniently assumed that the seed which comes from AAS research institutes must necessarily be pure and of high quality. This would be so, if adequate facilities are available and if proper seed production techniques were followed. Under existing situation it appears that the breeder seed programme also needs strengthening. It is also recommended that the Academy of Agricultural Sciences (AAS) should standardize the methods of production and maintenance of breeder seed for each crop.

Next in importance to the purity of the breeder seed is the purity of the foundation seed and its availability in adequate quantities. The production and distribution of foundation seed are important aspects of seed production programme as they determine the volume of high quality certified seed that would be available to the farmers at more than 3,500 cooperative farms. The foundation seed should be subjected to rigorous inspection by Central/Provincial Seed Inspection officials. Care should be taken to maintain the quality of the seed-material at field level, and during seed production, processing and storage. Similarly practice of multiplication of foundation seed from foundation seed till it looks fine should also be discouraged. The term 'certified seed production' is widely used to denote the production of commercial seed at 240 cooperative certified seed farms which is handed over to the other cooperative farms for raising crops. It should be ensured that it is available in pure condition and in adequate quantities.

Incentives for production of quality FS and CS are also lacking. Better price could work as incentive for more quality seed production.

**Seed Quality Control**

The essence of any seed production programme lies in quality control. Seed is different from grain only if certain qualities which are important from the point of view of genetic purity are preserved carefully. The seed production programme without quality control will result in failures. Therefore, seed quality monitoring and control will require utmost attention at every stage of seed production.
The certification of all classes of seed is mandatory. The seeds are certified by officials of the Provincial Seed Certification Centres and the field standards and seed quality standards are checked against the standards specified for certification. These standards need revision to bring them at par with international standards which are based on research and practicality.

Field quality control starts with field inspection prior to planting leading to approval of seed fields (field history, preceding crop, soil conditions, availability of irrigation water, slope, etc. should all be checked). Standard number of inspections and time of inspections should be followed from planting to harvesting and storage. Implementing proper seed field inspection scheme with trained inspection officials will lead seed farms to appreciate the difference between seed and grain production and thereby comply with seed production standards.

Field Inspections in respect of hybrid maize seed fields is a tool to evaluate the quality of seed production. The field inspection at appropriate crop growth stages is particularly important in respect of first generation hybrids of maize as these are expected to perform better than non-hybrid seed and farmers will not obtain desired results unless the hybrids are truly the type of crosses which they were intended to be. If seed which is not up to the mark and standards is certified, all users of seed will suffer. The agricultural programmes of the country will also suffer. Therefore, standards specified for seed certification by competent agency are required to be adhered to with firmness.

Seed project funded by UNDP and executed by FAO has established three seed testing laboratories in selected seed farms. These laboratories should follow International Seed Testing Association (ISTA) procedure to test the seed samples. It will ensure the uniformity in the procedure and results.

Upgrading of Central Seed Testing Laboratory at Central Seed Inspection Centre is desirable. Non-availability of chemicals and reagents is a major problem. It could be achieved by providing essential seed testing laboratory equipment, chemicals, reagents and other supplies in time. Supply of a desktop computer with printer will certainly help in maintaining record and generating reports.
The Central Seed Testing Laboratory must introduce a system of referral testing to ensure uniformity of seed testing in all the laboratories in the country. It should provide active leadership in developing the Provincial State Seed Testing Laboratories.

**Seed Processing and Packing**

In dealing with seeds, we deal with living material with the result that constant care is necessary at all stages of production, processing, storage etc. The main objective of seed processing is to preserve the viability of the seeds by removing all foreign matter and contaminating material. Seed cleaning and grading machines available at foundation seed farms are very old and inefficient. These are required to be replaced and the deficiencies in the functional seed cleaners are also required to be removed immediately.

Efficiency of recently procured new seed cleaning machines is poor if compared with similar machines manufactured by reputed companies. Sometime, such machines are purchased due to their lower prices compared to standard machines. Although price is an important consideration for project in making purchases, it should not be overemphasized when purchase decisions are made, especially on machines that have a direct bearing on seed quality.

Procurement of good quality seed threshing, processing and laboratory equipment from reputed and branded manufactures of Europe and other developed countries is not possible for various reasons and, thus, project ends up procuring poor quality equipment. It is affecting on quality of various outputs. It would be better if Project dialogues with the UNDP and other concerned authorities in FAO to help solving the problems reach to meaningful decisions since it is reflecting in the Projects’ image.

Upgrading of three foundation seed production farms with rehabilitation or reconstruction of most essential facilities for seed drying and storage buildings, rehabilitation of repairable equipment or their replacement and the provision of additional seed processing (threshing, cleaning, treatment and packaging) and storage equipment is urgently needed if these are to be developed as ideal seed farms.
The packing of seed is another weak area in the process of production of quality seed on these farms. Packaging comes at the end of processing operations. All the efforts taken in inspecting seed lots from the time of sowing to processing and all the care taken to preserve their viability through proper seed processing would be of no avail if steps are not taken to avoid physical adulteration of seed lots. Sometimes seed are packed in straw bags. Such bags neither could be sealed properly nor labelled. Beside this, storage and handling of seed in the seed stores in straw bags can become a cause of varietal mixing. It is recommended that seed bags of suitable material should be used so that these could also be properly labelled. It would be better if seed is packed in cotton and jute canvas, gunny bags or Polypropylene bags.

Proper storage is vital for all kinds of seeds. Seed storage is proper in some cooperative farm stores whereas, is poor with others. Storing cleaned and bagged seed on dusty floors and outside under unprotected condition might damage seed quality. In most of the cases the existing seed storage facilities require massive renovation.

Another development of great concern is the fact that in irrigated ecosystem, which contributes major share of the food production advances made so far, yield levels of high yielding varieties (non-hybrid) are getting plateaued and need to be improved through introduction of better varieties and optimization of management practices. Breeding and seed production programmes often go hand in hand to make an impact. Therefore, there should be strong coordination between AAS and seed production programme.

Linkage with International Organizations is very important to keep pace with the latest developments in agriculture. Effective linkage of AAS, Agricultural University and various crop research institutes with Regional and International sources of improved planting material especially with various centres of Consultative Group on International Agricultural Research (CGIAR) is necessary to procure new genetic material and technology. AAS should delineate agro-ecologies for targeted crops and on this basis establish international professional seed linkages for obtaining new / improved materials.

The policy of both “breed” and “test” should be followed in introduction of new improved plant varieties. It is usually best options for taking advantages of research at home and abroad.
Study and training visits of the scientists and technicians working in plant breeding and seed sector to the international institutions/organizations, International Maize and Wheat Improvement Centre, Mexico for maize; a few agricultural universities in the region like those in China and other neighbouring countries which have equivalent area in terms of crops and climate will be very helpful in advancing the research at home. One year long intensive training of the concerned scientists is considered ideal.

While introducing varieties from other countries the uniqueness of the growing conditions should be well understood to avoid differences in climate, soil and other agronomic factors.

**Organizational Structure of Seed Production in DPRK**

The general organizational pattern of the country’s government and tradition affect the organizational structure of the seed production programme. The Ministry of Agriculture has the main responsibility for ensuring that there is a healthy seed production programme that meets the needs of the farmers. The following organizations of the govt of DPRK are responsible for variety release and registration, seed production and quality control (Fig. 2)

**Organizational Chart**

<table>
<thead>
<tr>
<th>Organization/Institute</th>
<th>Seed Supply System/ Activities and Responsibilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ministry of Agriculture (MoA)</td>
<td>Registration of varieties.</td>
</tr>
<tr>
<td>State Variety Comparison and Test Committee</td>
<td>-variety testing and adaptive trials in-country</td>
</tr>
<tr>
<td></td>
<td>-variety release/description/recommendation</td>
</tr>
<tr>
<td>Academy of Agricultural Sciences (AAS)</td>
<td>32 different research institutes</td>
</tr>
<tr>
<td></td>
<td>-Rice Research Institute</td>
</tr>
<tr>
<td></td>
<td>-Maize Research Institute</td>
</tr>
<tr>
<td></td>
<td>-Central Veg. Institute</td>
</tr>
<tr>
<td></td>
<td>-Potato Research Institute</td>
</tr>
<tr>
<td></td>
<td>-variety breeding and development</td>
</tr>
<tr>
<td></td>
<td>-variety maintenance by breeder</td>
</tr>
<tr>
<td></td>
<td>-variety sourcing</td>
</tr>
<tr>
<td></td>
<td>-line selection/variety development in-country</td>
</tr>
</tbody>
</table>
Seed Production Dept, MoA
- breeder seed production
- training

Seed Production Division
25 Foundation Seed Farms
240 Certified Seed Farms
- central production/stock records and allocation
- foundation and certified seed production.
- quality control.

Central Seed Inspection Centre
10 Provincial Seed Inspection Centres
- crop inspection
- seed testing
- labelling/certification

Fig. 2. Organizational chart for seed related activities in DPR Korea

Besides, Improved Seed Production for Sustainable Agriculture project few International NGOs are also involved in seed production activities as a part of their larger agricultural programme. The multiplicity of donor agencies dealing in such a vital aspect of agriculture is certainly to be welcomed. It would be difficult to lay down rigidly the precise task of each agency and to enforce the same. However, to avoid overlapping of activities and waste of resources, it is necessary to demarcate the roles of these agencies in the seed development programme and adhere to such demarcation as far as possible.

In principle, the task of all concerned government institutions namely: Academy of Agricultural Sciences (AAS), Ministry of Agriculture (MoA) and 265 Cooperative Seed Farms is to provide to the farmers high quality seed of the best varieties bringing the fruits of research to the farmers’ doors in the quickest possible time. The Seed Projects supported by UNDP/FAO play an important role in realising this goal.

The Seed Department of the MoA through 240 co-operative seed farms annually produces approximately 156,000 tons of certified seed of various crops (MoA Report). It is an important question that how much seed out of 156,000 ton meets international standards. There is general belief that hardly 15% seed would meet the international seed standards.
**Seed Replacement Rate**

In fact, there is no need to produce such a large quantity of certified seed. It is not necessary to supply certified seed (CS) for each hectare of non-hybrid varieties every year. This is because 100% seed replacement rate (SRR) is a technical requirement only for hybrid crops. Except maize no other cereal crop has significant area under hybrid varieties. Research data and experience show that a 33% seed replacement rate (SRR) is an ideal replacement rate. No extra significant advantage is achieved by replacing total seed requirement of self-pollinated cereal crops every year by certified seed. Therefore, supply of 1/3rd certified seed of total requirement of non-hybrid varieties and 100% certified seed of hybrid varieties could ensure high crop productivity and change in varietal profile to replace old and degenerated varieties with new and superior varieties.

**Area Required to Produce Desired Quantity of Certified Seed and Seed Multiplication Ratio (SMR)**

Calculation of seed area and production depends upon the knowledge of the crop area to be sown, seed rate per hectare and average yield of seed crop (which will give the multiplication ratio), seed renewal period and seed multiplication stages. Based on the CFSAM data (2011-12) of area, yield and production and assuming that 100% of maize is under hybrid varieties, the total annual seed requirement of various classes is given in Table 18.

As per the national aggregate production of cereal food crops reported by CFSAM and prevalent seed rate the seed multiplication ratio (SMR) is very poor. It is only 1:37 for maize. It is much lower than multiplication ratio obtained under normal farming conditions. It may be due to use of very high seed rate and poor productivity. The total seed requirement has been worked out on the basis of a normal SMR considering that seed farms will have better facilities in comparison to grain producing farms.

<table>
<thead>
<tr>
<th>Ideal SRR (%)</th>
<th>Maize (Total hybrid) (**)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>100</strong></td>
<td></td>
</tr>
</tbody>
</table>

*Table 18. Annual ideal maize seed requirement*
The country seed production programme adheres to the limited four generation system of seed multiplication, namely, breeder, foundation-I, foundation-II and certified seed. In a seed production generation chain the quality of breeder seed, foundation seed and certified seed is of paramount importance. It is emphasised that all the agricultural production programmes mainly depend on the availability of quality seed responsive to various inputs on which heavy investment are being made.

DPRK has organizations essential for a successful seed programme. All operational components namely: plant breeding, varietal assessment and maintenance, seed production, processing, testing and distribution exist and are functional. The production of various classes of seed relies on the Academy of Agricultural Sciences (AAS) and cooperative seed farms, both are involved in an integrated seed production chain. Academy of Agricultural Sciences (AAS) produces breeder seeds in small quantities and same is multiplied on 25 cooperative foundation seed farms to produce foundation seeds. Foundation seeds are then multiplied on 240 cooperative certified seed farms for production of certified seeds. Certified seeds are usually those destined for commercial distribution to large numbers of farmers on a regional and national basis for the purpose of crop production.

### Production of Breeder Seed

Breeder seed production needs very specialized planting, threshing and cleaning equipment. Beside this, breeder seed cannot be multiplied in bulk like certified seed or commercial grain. Breeder seed production procedure and technique differ from crop to crop. In case of maize

<table>
<thead>
<tr>
<th>Seed multipication ratio</th>
<th>1:80</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical seed rate kg/ha</td>
<td>25</td>
</tr>
<tr>
<td>Area planted each year under certified seed</td>
<td>503,000</td>
</tr>
<tr>
<td>Breeder Seed (ton)</td>
<td>1.97</td>
</tr>
<tr>
<td>Foundation Seed-I (ton)</td>
<td>157.18</td>
</tr>
<tr>
<td>Foundation Seed-II (ton)</td>
<td></td>
</tr>
<tr>
<td>Certified Seed (ton)</td>
<td>12,575.00</td>
</tr>
</tbody>
</table>

Typical seed rate kg/ha: 25
Area planted each year under certified seed: 503,000
Breeder Seed (ton): 1.97
Foundation Seed-I (ton): 157.18
Foundation Seed-II (ton): 0
Certified Seed (ton): 12,575.00
breeder follows ear to row method where a breeder selects single heads/ears from individual plants of maize then progeny rows are planted from a bulk sample of the seed produced from individual heads/ears and finally a progeny block is planted from a bulk sample of seed produced by planting the bulked produce of a progeny row.

Under a typical generation chain breeder seed should be multiplied from nucleus seed, foundation seed from breeder seed and certified seed from foundation seed. However, it is observed that sometime AAS multiplies breeder seed in bulk from breeder seed itself and it is repeated several times. Similarly cooperative farms continue to produce foundation seed from foundation seed till seed physically looks fine. The practice of bulk increase of breeder seed and unlimited multiplication of foundation seed from foundation seed affects the quality of seed and this practice in vogue should be discontinued.

The practice of production of breeder seed in bulk requires serious examination in the light of technical issues involved in maintenance breeding. It will be better if strict protocol of nucleus/breeder seed production during multiplication of parental lines is followed. It could be ensured only by the concerned breeder. Facilities available at present at AAS stations for production of breeder seed require strengthening. Supply of suitable equipment for planting, harvesting, threshing and processing will help in production of breeder seed of desired quality and quantity. Proper breeder seed storage facilities will help in maintaining strategic stock of breeder seed to avoid every year production and to meet emergencies. Maintenance of buffer stock of breeder seed is a common practice in various countries.

Breeder seed constitutes the basis of all further seed production envisaged. The quantity and quality of breeder seed available are, therefore, of primary importance. It is suggested that:

- Standard procedures for breeder seed production should be laid down and followed for each cereal crop including maize.
- Requisite facilities in terms of personnel, processing and storage should be provided to maize research centres.
- System for an effective internal check on quality of breeder seed during field and seed stages needs to be introduced. Just checking of germination is not sufficient.
Foundation Seed

FS is the progeny of breeder seed. Its quality is very important for the certified seed cooperative farms. If the parent material is not good the progeny can naturally be no better. Therefore, requisite quality of the foundation seed could reduce the need for roguing to the minimum thereby reducing the cost of production and ensuring the specified quality standards. Therefore, strengthening of physical and knowledge infrastructures at foundation seed farms is very important. Under the existing standards, the term “Foundation Seed Stage-II” (FS-II) has been widely used. The term “FS-II” refers to an intermediate multiplication between foundation and certified seed. In respect of certain crops where the seed multiplication ratios are particularly low, it is necessary to have such an intermediate stage of multiplication. However, it is an irrelevant term in case of hybrid seed production. A few points worth mentioning in foundation seed production programmes of maize in DPR Korea are as follows:

- Adequacy of foundation seed of good quality is of vital importance in the seed production programmes of various crops. Department of Seed Management of the MoA organizes foundation seed production on 25 specialized farms located in different regions of the country.

- Sufficient quantity of FS-I should be produced to meet the requirement of certified seed (CS). The production and distribution of foundation seed are important aspects of seed production programme as they determine the volume of high quality certified seed that would be available to the farmers at other cooperative farms.

- The foundation seed should be subjected to rigorous inspection by Central/Provincial Seed Inspection officials. Care should be taken to maintain the quality of the seed-material at pre- and post-harvest stages.

- Practice of multiplication of foundation seed from foundation seed till it looks fine should also be discouraged and FS should be preferably multiplied from breeder seed. Under emergent situations, foundation seed can be multiplied from foundation seed itself and the produce is labelled as Foundation Seed Stage II. There should be no further multiplication from Foundation Seed Stage II.

- Prescribed number of inspections and time of inspections should be followed from planting to harvesting and storage. Implementing proper seed field inspection scheme with trained inspection officials will lead seed farms to appreciate the difference between
seed and grain production and thereby ensuring compliance with seed production standards.

- Availability of good level of technology in numerous fields including Seed Science and Technology and availability of crop scientists and technical staff to support the seed programme is not a problem. However, resource constraints at cooperative seed farms include non-availability of all agricultural essential inputs including suitable farm machineries, fertilizers, insecticides and pesticides, seed drying, processing and storage facilities. Adequate resources should be made available to each Foundation Seed farm.

- Upgrading of three foundation seed production farms with rehabilitation or reconstruction of most essential facilities for seed drying and storage buildings, rehabilitation of repairable equipment or their replacement and the provision of additional seed processing (threshing, seed cleaning, treatment and packaging) and storage equipment as required is urgently needed.

- Unfortunately, up-gradation and strengthening of seed production infrastructure and facilities at various seed production farms of DPR Korea cannot be achieved by on-going several projects under UNDP/FAO. Instead, massive intervention of the government is needed to expand the foundation laid out by various projects on seeds. The restrictions are affecting procurement of good quality equipment and machineries from reputed manufacturers of developed countries and also new genetic material from well known sources in public and private sectors.

- It is a general view that no investment can be considered to be too high and no effort too great in order to secure in full measures of the objectives of a country seed production programme. Therefore additional financial assistance to seed sector is urgently needed.

**Certified Seed Production**

While the arrangements for the production of breeder and foundation seed are important the farmer is most interested in the arrangements for certified seed production. The farmer comes into contact with the agricultural research and with new varieties mainly through the certified seeds that are made available to him. He judges the entire programme only by the quality of the certified seed and only to the extent that certified seed truly reflects the original qualities of the
seed evolved at the research stations of AAS which can bring the desired results in the farmers’ fields. A few points worth mentioning here are as follows:

- It is reported that 240 cooperative farms are designated to produce certified seed (CS). These farms are located in different regions of the country. It is believed that the areas of certified seed production are determined keeping in view the natural advantages of different regions. Areas where good quality seeds can be produced with minimum risks of diseases, pests or failures should be preferred. Quality of seed produced, reliability of seed production, yield per acre, cost of seed production, facilities for storage and transport should be the considerations in deciding areas of seed production.

- Field inspection of hybrid maize seed fields is a tool to evaluate the quality of seed produced. The field inspection at appropriate crop growth stages is particularly important in respect of first generation hybrids of maize as these are expected to perform better than non-hybrid seed and farmers will not obtain desired results unless the hybrids are truly the type of crosses which they were intended to be. If seed not conforming to minimum field and seed standards is certified and distributed, all users of seed will suffer. The agricultural programmes of the country will also suffer. Therefore, standards specified for certification are required to be adhered to strictly without exception.

**Seed Quality control**

It is important to assure production and distribution of good quality seed. Following points need to be taken into consideration to monitor seed quality:

- Provision of scientific crop management, prescribed isolation distance, adequate roguing, and proper harvesting in the production stage.
- Ensuring adequate drying to desired level of moisture.
- Adhering to processing protocols.
- Scientific storage.

Maintaining good seed quality through all these steps requires knowledge of what to do and commitment to high quality seed. Out of 156,000 t of CS produced every year in DPRK, hardly 15% might be of international standard. Maintaining seed quality seems major problem than production of seed. An optimist will always think that "there are no problems, there are only
opportunities”. Therefore, there is need to use all available opportunities to produce seed which meets minimum prescribed field and seed standards.

**Seed Certification**

A seed certification programme is one tool for producing seed of specified standards. In DPRK the quality level of certified seed is officially recognised and controlled. Under MoA there is a separate Central Seed Inspection Centre in Pyongyang. It has 10 Provincial Seed Inspection Centres and a central seed testing laboratory. Each Provincial Centre is also equipped with a seed testing laboratory to conduct standard tests to determine moisture, physical purity and germination. All three foundation seed farms supported by a few FAO projects have recently received the necessary seed testing equipment. The Central Seed Inspection Centre in Pyongyang is headed by a Director. It has 5 different branches for inspection of seed in field and laboratory. More than 46 experts work in the centre.

The main responsibility of the centre is to inspect seed crops at 25 foundation seed farms. Centre also has authority to carry out the seed testing of breeder seed samples besides intervening in the disputed cases of foundation and certified seeds. The Central Seed Inspection Centre has a modestly equipped seed lab. However, Centre lacks transport facility which is a must to visit all the foundation seed farms.

The seed inspectors working at central and provincial centres regularly conduct field inspections of seed crop in the field. The observations are recorded on a simple sheet of paper. Field inspection of seed crops is an essential step in verifying conformity of seed crops to specified standards. All observations are required to be recorded on a seed inspection report suitably designed for this purpose. Beside this, simple but uniform and statistically-reliable inspection methods are now being used by most seed production programmes in different countries. The same could be practiced at seed farms. Format of a typical field inspection reports is at Annexure III. During field inspections several inspection are carried out to examine the seed crop in different growth stages.

For all crops, five counts are taken for any area up to 2 ha and an additional count is taken for every additional 2 ha as given below:
<table>
<thead>
<tr>
<th>Area of the seed field (ha)</th>
<th>Number of counts to be taken</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 2</td>
<td>5</td>
</tr>
<tr>
<td>Above 2 up to 4</td>
<td>6</td>
</tr>
<tr>
<td>Above 4 up to 6</td>
<td>7</td>
</tr>
<tr>
<td>Above 6 up to 8</td>
<td>8</td>
</tr>
<tr>
<td>Above 8 up to 10</td>
<td>9</td>
</tr>
</tbody>
</table>

In any inspection, if the first set of count shows that the seed crop does not conform to the prescribed standards for any factor, a second set of counts should be taken for that factor. However, when the first set of counts shows a factor more than twice the maximum permitted, it is not necessary to take a second set of counts. Two sets of counts are called double counts. Taking double counts for a factor is necessary, if in the first set of counts, occurrence of the factor is more than the maximum permitted, but not more than twice the permissible level; and not necessary, if in the first set of counts, occurrence of the factor is less than or equal to the maximum permitted.

The number of plants/heads comprising a single count in maize is 100 plants.

Usually, the following observations are specifically recorded in the report:

- Raised from seed whose source is approved (FS from BS and CS from FS),
- Grown on a field area which satisfies the prescribed land requirements as to previous crop(s), to prevent contamination by volunteer plants and disease spread by pathogens,
- Provided with the prescribed isolation distance from contaminant,
- Planted in the prescribed ratios of female (seed) and male (pollinator) parents in the case of hybrid maize seed production,
- Hybrid seed production fields of maize are carefully monitored for unwanted pollen sources,
- Properly rogued to remove contaminating factors such as shedding tassels in maize
crosses, off types, diseased plants/ears, objectionable weeds, and inseparable other crop seeds so as to conform to the standards prescribed for these factors,

- True to the varietal characteristics descriptive of that variety, and
- Harvested properly to avoid mechanical admixture.

**Seed Standards:**
The seed standards followed for certification in DPRK for maize is at Annexure-1. It is true that extremely rigorous and rigid quality evaluation measures can achieve highest quality but they may make seed cost too high. Seed quality evaluation measures should, therefore, be designed to ensure that reasonable standards of seed quality are met, but that seed cost is not prohibitive, or reasonable quantity of seed is not available.

During updating/revision of certification standards, care should be taken to make them more clear, common, complete, accurate, simple and realistic to make the task of certification easy.

The system of assembly-line approach combined with management by objectives has particular relevance to all the three foundation seed farms run through professional staff posted there. Their dedication and commitment for quality is very important. Quality of seed is affected by a host of factors, at all stages, namely, production of the raw seed in the field, harvesting, drying, grading, seed treatment and other aspects of processing, transport as well as seed storage.

The cost of unprocessed seed production will be substantially reduced if following measures are taken to ensure the right quality of the unprocessed seed:

- Ensure requisite quality of the breeder and foundation seed so that the need for roguing may be reduced to the minimum. If the parent material is not good the progeny can naturally be no better.
- Effective action by the farm workers by way of roguing in accordance with the certification standards specified by MoA.
- Technical guidance to farm staff responsible for seed production by the staff of Provincial Inspection Centre, AAS and research institute’s scientists.
• Regular and timely inspections and strict adherence to the standards by the certification officials.

• Proper drying is essential to seed quality because seed drying helps seeds maintain their ability to germinate and their vigour for a longer period.

• Drying controls mould growth and the activity of the other organisms that reduce the quality of stored grain.

• Drying reduces seed discoloration.

Drying is not a high technology luxury. Seeds must be dried immediately after harvest, to the moisture content safe for the crop seed and storage period. Serious problem of seed drying exists on all three seed farms in DPR Korea. There is hardly any good cemented seed threshing-cum-drying floor on any farm. During rain free season seed could be dried under natural condition. The sun is the most economical heat source for seed drying. However, sun drying can be used to dry seed as long as the Relative Humidity (RH) of the air is lower than the RH in equilibrium with the moisture content of the seed. If RH of the air is above 70% then seed will gain moisture and it may be above maximum specified limit. Artificial drying is essential for costly foundation seed of hybrid maize to avoid any damage to valuable seed. If seed is harvested at 30 percent moisture, the moisture must be brought down to 12-14 percent within a few days. Even with crops which are harvested at lower or safe moisture percentages, it would be better to dry them quickly so that the seed stocks could be processed without any delay and the risk of contamination etc. kept in the minimum.

**Problem of Seed Processing**

Setting up and maintaining a seed processing plant requires large capital investments. If properly equipped and managed, it is a tremendous asset to a seed farm otherwise, it is a big liability. Machine seed processing is most serious problem at all three foundation seed farms in DPR Korea. Majority of the processing machineries, especially those with low capacity do not move seed mechanically, manual labour is required to feed the seeds into cleaners and remove cleaned seeds. The frequent breakdown of even these old seed cleaners is quite often. The main objective of seed processing is to preserve the viability of the seeds from harvesting till sowing by removing all foreign matters and contaminating materials including weed seeds. Effective cleaning requires the adoption of suitable mechanical means depending on the nature of the crop,
condition of the lot and extent and type of contaminants. There are many types of efficient cleaning machines available to clean unprocessed seed in other countries but machineries available at various seed farms of DPR Korea are very old and inefficient. These are required to be replaced and the deficiencies in seed cleaners also need to be removed as early as possible.

Demonstration trial results of some of the newly procured seed cleaner under various on-going FAO project have not been very encouraging. The efficiency of the recently procured new seed cleaning machines is poor in comparison to the similar machines manufactured by reputed companies. Sometime, such machines are purchased due to their lower prices compared to standard machines. Procurement of standard seed threshing and processing and laboratory equipment from reputed manufactures is a major problem and needs to be addressed.

**Problem of Seed Packaging:**

Packaging comes at the end of processing operations. All the efforts taken in inspecting seed lots from the time of sowing to processing and all the care taken to preserve their viability through proper seed processing would be of no avail if steps are not taken to avoid physical adulteration of seed lots and for identification of particular lots. The processed seeds are, therefore, generally packed in various types of containers and sealed to avoid any physical adulteration and easy identification. It appears that in DPR Korea main aim of packing of seed at seed farms is to put them into units for easy handling and transport and not specifically as seed bag which are usually properly sealed and labelled.

Unfortunately, there is shortage of good packaging material. There are instances where seed is packed in straw bags. Storage and handling of seed in the seed stores in straw bags can become a cause of varietal mixing. It would be better if seed bags of suitable material are used so that these could also be properly labelled. Use of cotton and jute canvas, gunny bags or polypropylene bags is considered safe for packing of seed.

**Problem of Proper Seed Storage:**

Availability of proper seed storage facilities is another serious problem in DPR Korea. It is necessary to provide storage accommodation of the requisite standard and to ensure proper
stacking with pallets at regular intervals between the requisite number of bags and proper arrangements for aeration. Suitable seed stores with necessary arrangements for keeping down the temperature and humidity within the prescribed limits are necessary. Hardly, any suitable seed storage facility exists on any seed farms, although under certain projects, some seed stores have been constructed.

In fact, the condition of all essential facilities including seed storage structures is not up-to the desired level in DPR Korea. Over a period of time, this could happen anywhere and this is quite natural. However, in order to keep the things in good conditions, infrastructure renovations are required at regular intervals. The time is ripe for renovation of facilities on all three farms, namely, Maekjon, Daesong, and Unpa. If not attended to right now, it may have very strong bearing on the quality of seed and post-harvest losses of good seed.

During technical discussion while implementing seed projects with agronomists and seed analysts, several production and quality control related issues were raised. Most questions were focussed on the difference in procedures and techniques of seed production followed in other countries compared to what is being done in DPR Korea. The seed rate of different crops followed at the farm widely differs from the standard seed rate followed in other countries. Farm manager mentioned the seed rate for maize as 40 kg/ha (direct sowing) and 25 kg/ha (transplanting). It was explained that main purpose of recommending standard seed rate is to obtain a proper population level in the field. An appropriate seed rate depends on germination percentage and seed size.

Summary of maize production technology as reported by the officials of the farm in DPRK is as follows and this should be taken into account for seed production crop as well.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Direct sowing</th>
<th>Nursery sowing time</th>
<th>Transplanting time</th>
<th>Harvesting time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>Early May</td>
<td>--</td>
<td>--</td>
<td>Sept-Oct</td>
</tr>
<tr>
<td>Maize (transplanted)</td>
<td>---</td>
<td>Early April</td>
<td>Early May</td>
<td>Sep-Oct</td>
</tr>
</tbody>
</table>
Informal training on the procedure of taking field counts during field inspection of maize crop and use of various seed testing equipment should be regularly conducted.

The condition of threshing floor, machinery shed, seed processing shed is very poor and unfit for seed operations. In fact, they need massive renovation work.

Seed processing plant including Sheller, cleaner, grader and seed treatment machines also needs to be modernised with smooth functionality.

In DPR Korea, there is lack of proper marking or labelling on certified seed bags. In some cases seed is packed in large straw bags. It seems that because seed is not meant for commercial sale and reserved for the use at other cooperative farms, the concerned personnel have not realized the value of proper marking and labelling of seed bags. But standard and common practice in seed production programmes needs to be followed in seed production programmes of DPR Korea. Moreover, there is also a requirement of Seeds Act.

Maize hybrid varieties suitable for different elevations are as follows and their seed production should get due priority (Table 19).

**Table 19. Maize hybrids suitable for DPR Korea**

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Elevation (Meter)</th>
<th>Hybrid variety</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Up to 300</td>
<td>Hamnam No 3</td>
</tr>
<tr>
<td>2</td>
<td>Up to 400</td>
<td>Hamnam No 4, 10 and 11, Unsam No 9 and 10 and Pyongnam No 13</td>
</tr>
<tr>
<td>3</td>
<td>Up to 500</td>
<td>Hamnam No 9</td>
</tr>
</tbody>
</table>

**Women and Seed Production**

Since women have been traditionally seed selectors, they have a natural advantage in organizing scientific seed production programmes. It is therefore important to consult women about criteria to be used in the breeding of new varieties and to involve women in programmes for the adoption of improved varieties. Women’s needs, skills, knowledge, and views need to be taken into account with respect to:
• varietal characteristics, both desirable and undesirable;
• seed quality of new varieties, and methods of obtaining and ensuring good quality seed (e.g., selection of best panicles, storage of the panicles, row-sowing of seeds from each panicle separately to test the seed purity);
• varietal identification;
• interaction with weeds, insect pests and pest predators and soil conditions;
• tolerance to drought, floods, temperature, solar radiation;
• drying and storage characteristics of grain, and relation to milling recovery;
• quality of by-products (e.g., suitability for animal feed, fuel requirements, fencing); and
• cooking and eating preferences.
ANNEX - I. Minimum Seed Certification Standards (DPRK)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Factor</th>
<th>BS FI</th>
<th>FS FI</th>
<th>CS F I</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>F II</td>
<td>F II</td>
<td>F III</td>
</tr>
<tr>
<td>Maize</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single Cross</td>
<td>Purity (minimum)%</td>
<td>X</td>
<td>98</td>
<td>97</td>
</tr>
<tr>
<td></td>
<td>Inert matter (maximum) %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Germination (minimum) %</td>
<td>X</td>
<td>95</td>
<td>93</td>
</tr>
<tr>
<td></td>
<td>Shedding tassels (max)</td>
<td>X</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Moisture (maximum) %</td>
<td>X</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Seeds of other color</td>
<td>X</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Single cross, Double cross &amp; Three-way cross hybrids</td>
<td>Purity (minimum)%</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Inert matter (maximum) %</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Shedding tassels (max)</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Germination (minimum) %</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Seeds of other color</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Moisture (maximum) %</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Variety</td>
<td>Purity (minimum)%</td>
<td>99.8</td>
<td>98</td>
<td>97</td>
</tr>
<tr>
<td></td>
<td>Inert matter (maximum) %</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Germination (minimum) %</td>
<td>90</td>
<td>95</td>
<td>93</td>
</tr>
<tr>
<td></td>
<td>Seeds of other colour</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Moisture (maximum) %</td>
<td>14</td>
<td>14</td>
<td>14</td>
</tr>
</tbody>
</table>
Minimum Isolation Distance Specified for Maize Seed Crop

<table>
<thead>
<tr>
<th>Crop</th>
<th>Breeder Seed &amp; Foundation Seed</th>
<th>Hybrids and Certified Seed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>300</td>
<td>200</td>
</tr>
</tbody>
</table>

(English translation of MSCS from Korean was provided by Mr. Jon Jong Nam, Senior Officer, External Cooperation Department, Ministry of Agriculture (MoA) and Mr. Chang Su Am Senior Officer, Seed Management Department, MoA)

NB: The minimum prescribed germination for various classes of seed of maize in DPR Korea as per above table is 90 to 95 % and this is not in conformity with international norms. This may be brought down to 80 to 85 %.
Annex – II. Crop Seed Law of DPRK

(Date of Issue: 20th December 2011)

The Govt. of DPRK has enacted a Crop Seed Law (Seed Act) superseding Order No 44. It has 6 Chapters and 53 Articles dealing with registration and release of plant varieties, production of seed of various classes, responsibility of production and quality control and disposal of leftover seed, if any. The Seeds Act, if properly enforced, will lead to the upgrading of the quality of seeds.

Chapter 1 deals with General Provisions (.Article-1-6), Chapter-2 Breeding and Introduction of Crop Seed (Article-7-15), Chapter-3 Seed Production (Article-16-24) Chapter-4 Seed Inspection (Article- 25-33), Chapter-5 Storage and Use of Seed (Article-34-44) and Chapter-6 Guidance and Control on Seed Sector (Article-45-53).

The legislation is published in Korean language and English version is not available. Even copy of Korean version is not accessible. A very crude English translation of different Articles provided by the counterpart is given below. It would provide a very rough idea about the legislation. Considering that recently a full-fledged seed legislation has been enacted, it would be proper if future seed projects are drafted/modified according to the law of the land. Therefore, an authentic translation of the Act is necessary.

Chapter-1 General Provision (Principles of Seed Crop Law)

Article-1 Function of seed law (activities regulated by the present law)
Article-2 Principles of crop breeding
Article-3 Principles of crop seed production
Article-4 Principles of seed inspection
Article-5 Principles of seed use
Article-6 Exchange and cooperation in seed sector with friendly countries

Chapter-2 Breeding and Introduction of New Crop Seed

Article-7 Production planning of seed according to the requirement
Article-8 Breeding of suitable plant varieties
Article-9 Introduction of new plant varieties
Article-10 Testing of plant varieties for uniqueness
Article-11 Registration of new plant varieties
Article-12 Release of plant varieties for cultivation
Article-13 Protection of Plant Breeders’ right
Article-14 Conservation of plant genetic resources
Article-15 Use of germplasm

Chapter-3 Seed Production
Article-16 Principles of seed planning
Article-17 Estimation of seed demand
Article-18 Seed production centres
Article-19 Production of FS
Article-20 Inspection of FS
Article-21 Principles of seed production arrangements
Article-22 Specifications of seed
Article-23 Technical requirement of seed production
Article-24 Harvesting and processing of seed

Chapter-4 Seed Inspection
Article-25 Principles of seed inspection, seed production and seed storage
Article-26 Seed Inspecting institutes and their responsibilities
Article-27  Qualification of seed inspector
Article-28  Seed testing equipment
Article-29  Objectives of seed inspection
Article-30  Seed inspection method
Article-31  Standards for seed inspection and evaluation
Article-32  Control on seed inspection
Article-33  Report of seed inspection

Chapter-5 Storage and Use of Seed

Article-34  Compliance of technical requirements
Article-35  Institutes responsible for seed storage
Article-36  Technical requirements of seed storage
Article-37  Seed validity and disposal of seed
Article-38  Distribution and sale of seed
Article-39  Disposal of rejected seed
Article-40  Transport of seed
Article-41  Seed treatment
Article-42  Seed planting rate
Article-43  Management of surplus seed
Article-44  Import and export of seed

Chapter-6 Guidance and Control of Seed Sector

Article-45  Major Principles in guiding and control for crop seed sector
Article-46 Guiding Principles for crop seed sector
Article-47 Provision for crop seed sector
Article-48 Development of seed science and technology
Article-49 Increasing technical capacity of seed sector
Article-50 Compensation for surplus seed
Article-51 Control on seed sector
Article-52 Recovery and compensation for damaged seed
Article-53 Penalties and responsibilities

Annexure III. Field Inspection Report Format for Maize

Field No: Report No:
Date of sowing: Date of inspection:
Expected date of harvest: Time: From To

I. Name of seed farm:

2. County:

3. Location of the farm:

4. Code/Hybrid designation: 5. Class of seed:

6. Female parent: Male parent:

7. Total acreage under production of this seed crop:

8. Acreage of the field: 9. No. of field inspections: 10. Planting ratio:

11. Are both ends of male rows marked? .

12. Method of marking male rows:


14. Stage of growth of contaminant:

15. Stage of seed crop at this inspection:

16. Field counts: (Take 100 plants per count)
<table>
<thead>
<tr>
<th>Count No</th>
<th>Inbred line/Composite /OP and female parent of maize cross</th>
<th>Female parent of maize cross</th>
<th>Inbred line/Composite /OP and female parent of maize cross</th>
<th>Male parent of maize cross</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Receptive silks</td>
<td>Shedding tassel</td>
<td>Off types with shedding tassel</td>
<td>Off types with shedding tassel</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
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<td>.</td>
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<tr>
<td>.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

17. Side of field from which inspection was started:
18. Crop condition:
19. No. of times detasselled:
20. Frequency of detasselling:
21. Was detasselling done at inspection time?
22. Quality of seed production work:
23. Does this crop conform to the standards for certification?
24. Estimated seed yield (t/ha):
25. Was farm manager or his representative present at inspection time?
26. Remarks:

Signature of Farm Manager       Signature of Inspector
Annex – IV. Recommendations for Adoption Based on Compiled Information in Maize Breeding and Seed production Manual

The Author has included the maize seed standards as being practiced in DPR Korea and has highlighted the fact that some harmonization is needed in DPRK procedures and seed standards to bring them at par with internationally accepted norms.

1. Considering all pros and cons of DPR Korea, it is recommended that hybrid maize breeding should remain the main breeding activity of all concerned in DPR Korea where Pyongyang Agriculture University should take the lead role in implementing the hybrid maize breeding programme at the main research stations. The focus should be on inbred line development, test of combining ability, development of single crosses, three-way crosses and double crosses.

2. Characters needing special attention during line development and development of hybrids should be those having positive correlation with grain yield. Some of these characters are total plant weight, stover weight, grain fill rate, harvest index, ear length, ear diameter, kernel depth, shelling percentage and kernel weight besides characters of special importance under DPRK conditions, like cold tolerance and resistance to local diseases and pests.

3. There is need to have linkage with the International Centre for Maize and Wheat Improvement (CIMMYT), Mexico to have access to superior germplasm lines as introduction of germplasm from one area to another was, and continues to be an important breeding method. These lines are easily available subject to signing of Material Transfer Agreement (MTA).

4. Based on information presented on isolation distance, off types and seed standards for various kinds and classes of seeds, the following standards need to be adopted by seed production organizations in DPR Korea and the standards prescribed by DPR Korea which are slightly at variance, need to be harmonized with the following field and seed standards:

**Recommended isolation distance (m), off types, and seed standards for seed production programme of hybrids and parents of maize:**

<table>
<thead>
<tr>
<th>Contaminants</th>
<th>Foundation seed</th>
<th>Certified</th>
</tr>
</thead>
</table>

93
<table>
<thead>
<tr>
<th><strong>Maize with same kernel colour and texture</strong></th>
<th>Inbred</th>
<th>Single cross</th>
<th>Hybrid</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Maize with different kernel colour and texture</strong></td>
<td>400 m</td>
<td>400 m</td>
<td>200 m</td>
</tr>
<tr>
<td><strong>Field of same inbred/hybrid seed production not conforming to minimum seed certification standards</strong></td>
<td>600 m</td>
<td>600 m</td>
<td>300 m</td>
</tr>
<tr>
<td><strong>Field of other hybrid having common male parent conforming to minimum seed certification standards</strong></td>
<td>-</td>
<td>5 m</td>
<td>5 m</td>
</tr>
<tr>
<td><strong>Field of other hybrid having common male parent not conforming to minimum seed certification standards</strong></td>
<td>-</td>
<td>400 m</td>
<td>200 m</td>
</tr>
<tr>
<td><strong>Field of other hybrid having different parent</strong></td>
<td>-</td>
<td>400 m</td>
<td>200 m</td>
</tr>
<tr>
<td><strong>Teosinte</strong></td>
<td>600 m</td>
<td>600 m</td>
<td>200 m</td>
</tr>
<tr>
<td><strong>Off type plants that have shed or shedding pollen when 5% or more of the plants in the seed parent have receptive stigma</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Off type plants (%)</strong></td>
<td>0.20</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Off type plants in male parent (%)</strong></td>
<td>-</td>
<td>0.20</td>
<td>0.50</td>
</tr>
<tr>
<td><strong>Off type plants in female parent (%)</strong></td>
<td>-</td>
<td>0.50</td>
<td>1.00</td>
</tr>
<tr>
<td><strong>Total of off type pollen shedding tassels including off types tassels observed in previous inspections (%)</strong></td>
<td>-</td>
<td>1.00</td>
<td>2.00</td>
</tr>
<tr>
<td><strong>Off type plants in seed parent in final</strong></td>
<td>-</td>
<td>0.20</td>
<td>0.50</td>
</tr>
<tr>
<td>inspection (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Seed standards</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pure seed (%) minimum</td>
<td>98</td>
<td>98</td>
<td>98</td>
</tr>
<tr>
<td>Inert matter (%) maximum</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Other crop seed (number/kg) maximum</td>
<td>5</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Weed seed (number/kg) maximum</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Other distinguishable varieties seed (number/kg) maximum</td>
<td>5</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Germination (%) minimum</td>
<td>80</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Moisture (%) maximum not in vapour proof container</td>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Moisture (%) maximum in vapour proof container</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>

5. In view of great value of wealth of scientific information compiled in Maize Breeding and Seed Production Manual including reference to certain key publications widely acclaimed and read by maize scientists, it will be highly desirable if this publication is published in English and later on translated into Korean language so that DPRK scientists and students in agricultural university and those engaged in practical breeding and seed production of maize and in key agricultural policy formulations have an access to real information world-wise. As a consequent, the farming community in DPRK will be benefitted through development of superior maize hybrids and availability of hybrid seeds in adequate quantity. This can work as a stimulus for similar publications in other crops as well.
References

Hayes, H. K. 1963. A Professor’s Story of Hybrid Corn. Burgess Minneapolis, USA.


FAO’s Medium Term Plan 2014-17, Strategic Objectives (SO)

SO 1. Contribute to the eradication of hunger, food insecurity and malnutrition;
SO 2. Increase and improve provision of goods and services from agriculture, forestry and fisheries in a sustainable manner;
SO 3. Reduce rural poverty;
SO 4. Enable more inclusive and efficient agricultural and food systems at local, national and international levels; and
SO 5. Increase the resilience of livelihoods to threats and crises.

FAO’s Regional Priority Framework for Asia and the Pacific 2010-2019 (RPFAP)

1. Strengthening food and nutritional security;
2. Fostering agricultural production and rural development;
3. Enhancing equitable, productive and sustainable natural resource management and utilization;
4. Improving capacity to respond to food and agricultural threats and emergencies; and
5. Coping with the impact of climate on food and agriculture.

Country Programming Framework 2012-2015

The Country Programming Framework 2012-2015 (CPF) for the Democratic People’s Republic of Korea (DPR Korea) is co-owned by the Government of DPR Korea. The CPF, evolved after extensive consultation and deliberations, documents well specified 17 intended outcomes in the following five identified priority areas:

A. Strengthening national food and nutritional security;
B. Improving natural resource management;
C. Improving rural livelihood;
D. Coping with climate change; and
E. Strengthening institutional capacity for agricultural research, extension and administration.